HYDRAULIC SYSTEM & CONTROL IT THROUGH PLC

This credit consists of four units. The first unit presents the Basic Principals of a Hydraulic system which is helpful to develop a basic knowledge about Hydraulic System. The second unit describe the different types of Hydraulic components and their symbols. Third unit deals with electro hydraulic devices and the final unit of this credit give some example of programming and project.

Topics

UNIT-1 Basic Principals of Hydraulic System

UNIT-2 Different Type of Hydraulic Components and Their symbols.

UNIT-3 Control the Hydraulic system through electrical devices (Electro Hydraulic).

UNIT-4 Examples of electro Hydraulic Programming and control it through P.L.C

UNIT-1 Basic Principals of Hydraulic System

Objective:

Skill:

At the end of this unit trainees shall be able to

1. Understand those Principals which were work behind a Hydraulic system.

Knowledge:

At the end of this unit trainees shall be able to

1. Demonstrate the basic working principal of Hydraulic system.
2. Know about different type of fluid flow.

Guidelines to Instructor:

Explain the principle of Hydraulic system.

Structure:

1. Introduction
2. Hydraulic Principals.
3. Fluid Flow.

1. INTRODUCTION

Hydraulic systems are extremely important to the operation of heavy equipment. Hydraulic principles are used when designing hydraulic implement systems, steering Systems, brake systems, power assisted steering, power train systems and automatic Transmissions. An understanding of the basic hydraulic principles must be Accomplished before continuing into machine systems.
Hydraulics plays a major role in mining, construction, agricultural and materials handling equipment.
Hydraulics are used to operate implements to lift, push and move materials. It wasn't until the 1950s that hydraulics were widely used on earthmoving equipment. Since then, this form of power has become standard to the operation of machinery. In hydraulic systems, forces that are applied by the liquid are transmitted to a mechanical mechanism. To understand how hydraulic systems operate, it is necessary to understand the principles of hydraulics. Hydraulics is the study of liquids in motion and pressure in pipes and cylinders.

• why are hydraulic systems used?

There are many reasons. Some of these are that hydraulic systems are versatile, efficient and simple for the transmission of power. This is the hydraulic system's job, as it changes power from one form to another.
The science of hydraulics can be divided into two sciences:

- Hydrodynamics
- Hydrostatics.

❖ hydrodynamics

This describes the science of moving liquids.

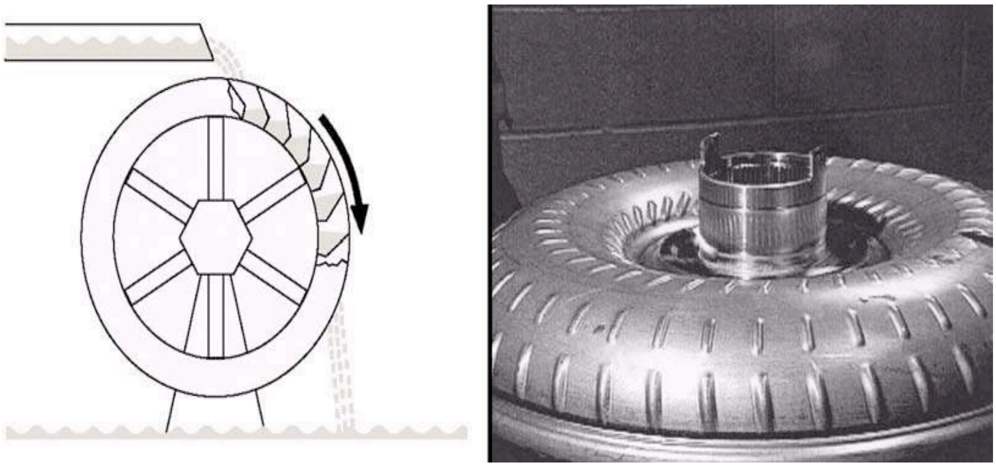


Figure 1 - a & b

Applications of hydrodynamics:

1. water wheel or turbine; the energy that is used is that created by the water's motion (Figure 1a)
2. Torque converter (Figure 1b).

❖ Hydrostatics

This describes the science of liquids under pressure. Applications of Hydrostatics:

1. hydraulic jack or hydraulic press
2. Hydraulic cylinder actuation.

In hydrostatic devices, pushing on a liquid that is trapped (confined) transfers power. If the liquid moves or flows in a system then movement in that system will happen. For example, when jacking up a car with a hydraulic jack, the liquid is moved so that the jack will rise, lifting the car. Most hydraulic machines or equipment in use today operate hydrostatically.

2. HYDRAULIC PRINCIPALS

There are several advantages for using a liquid:

1. Liquids conform to the shape of the container.
2. Liquids are practically incompressible.
3. Liquids apply pressure in all directions.

❖ liquids conform to shape

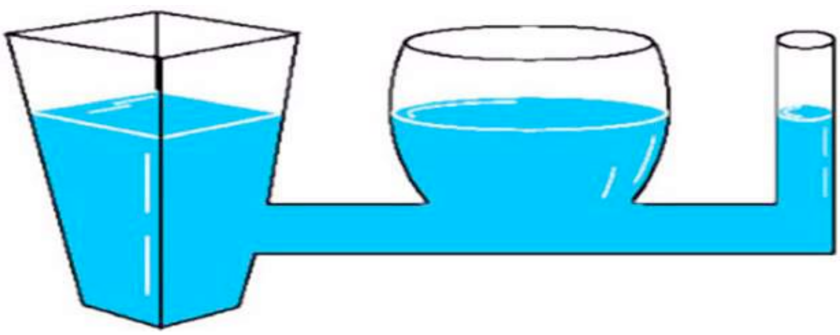


Figure 2

Liquids will conform to the shape of any container. Liquids will also flow in any direction through lines and hoses of various sizes and shapes. We have three oddly shaped containers shown in Figure 2, all connected together and filled to the same level with liquid. The liquid has conformed to the shape of the containers.

- **a liquid is practically incompressible**

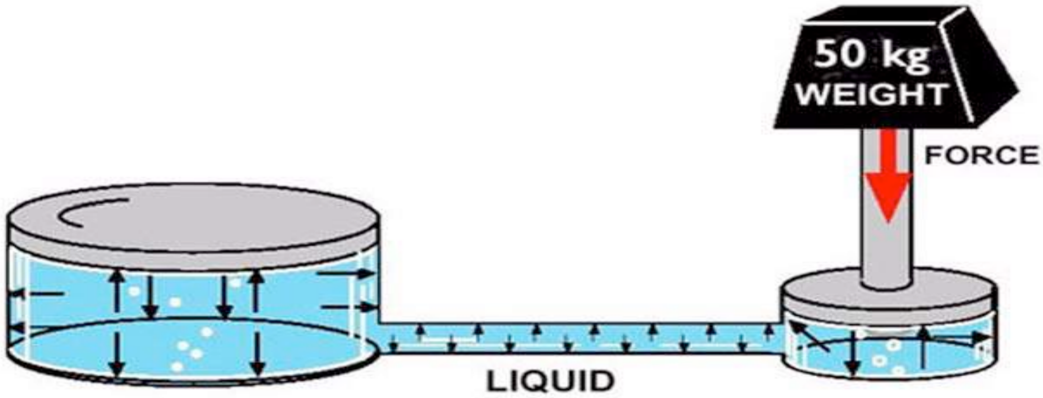


Figure 3

Hydraulic oil compresses approximately 1 - 1.5% at a pressure of 3000 psi (20,685 kPa). For machine hydraulic applications, hydraulic oil is considered as ideal and doesn't compress at all.

When a substance is compressed, it takes up less space. A liquid occupies the same amount of space or volume even when under pressure.

Gas would be unsuitable for use in hydraulic systems because gas compresses and takes up less space.

- **liquids apply pressure in all directions**

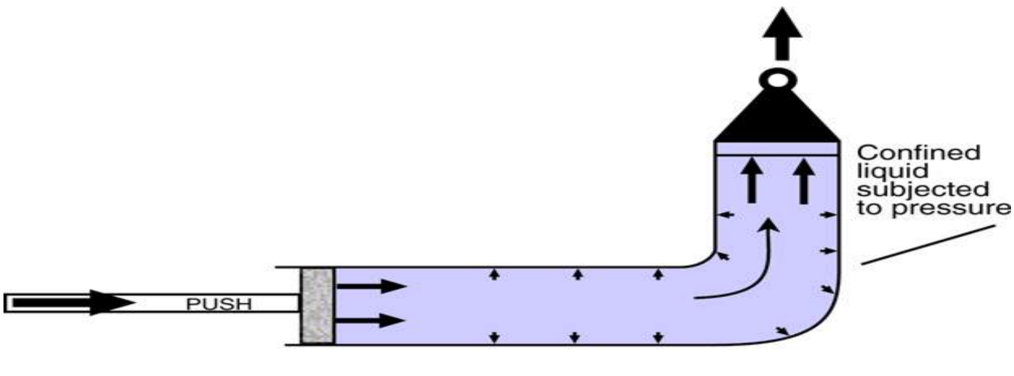


Figure 4

There is equal distribution of pressure in a liquid. The pressure measured at any point in a hydraulic cylinder or line will be the same wherever it is measured (Figure 4).

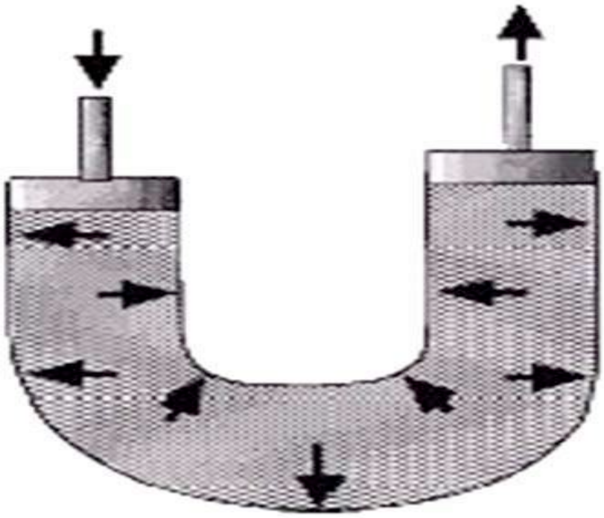


Figure 5

When a pipe connects two cylinders of the same size (Figure 5), a change in volume in one cylinder will transmit the same volume to the other. The space or volume that any substance occupies is called ‘displacement’. Liquids are useful for transmitting power through pipes, for small or large distances, and around corners and up and down. The force applied at one end of a pipe will immediately be transferred with the same force to the other end of the pipe.
Most hydraulic systems use oil, because it cannot be compressed and it lubricates the system.

Water would be unsuitable because:
1. it freezes at cold temperatures and boils at 100^oC
2. it causes corrosion and rusting and furnishes little lubrication.

- **purpose of the fluid**

Many types of fluids are used in hydraulic systems for many reasons, depending on the task and the working environment, but all perform basic functions:

First, the fluid is used to transmit forces and power through conduits (or lines) to an actuator where work can be done.

Second, the fluid is a lubricating medium for the hydraulic components used in the circuit.

Third, the fluid is a cooling medium, carrying heat away from the “hot spots” in the hydraulic circuit or components and discharging it elsewhere.

And **fourth**, the fluid seals clearances between the moving parts of components to increase efficiencies and reduce the heat created by excess leakage.

- **fluid power**

In the seventeenth century, a French Philosopher and Mathematician named Blaise Pascal, formulated the fundamental law which forms the basis for hydraulics.
Pascal's Law states:
"Pressure applied to a confined liquid is transmitted undiminished in all directions, and acts with equal force on all equal areas, and at right angles to those areas."

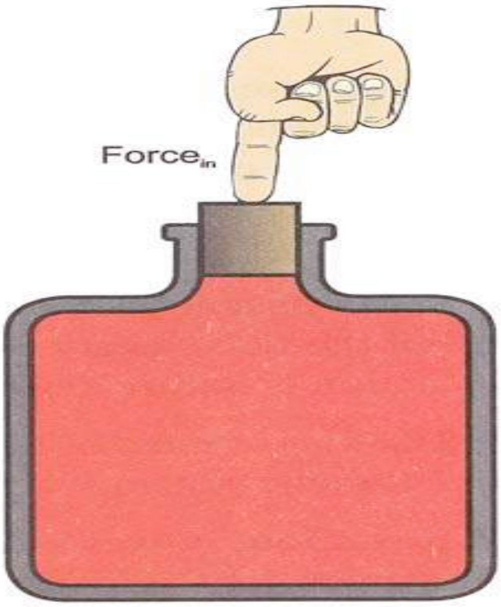


Figure 6 - Applying pressure to a liquid

This principle, also referred to as the laws of confined fluids, is best demonstrated by considering the result of driving a stopper into a full glass bottle (Figure 6).

Figure 7 - Container bursting due to pressure

Because liquid is essentially incompressible, and forces are transmitted undiminished throughout the liquid and act equally on equal areas of the bottle, and the area of the body of the bottle is much greater than the neck, the body will break with a relatively light force on the stopper. Figure 7 illustrates this phenomenon.

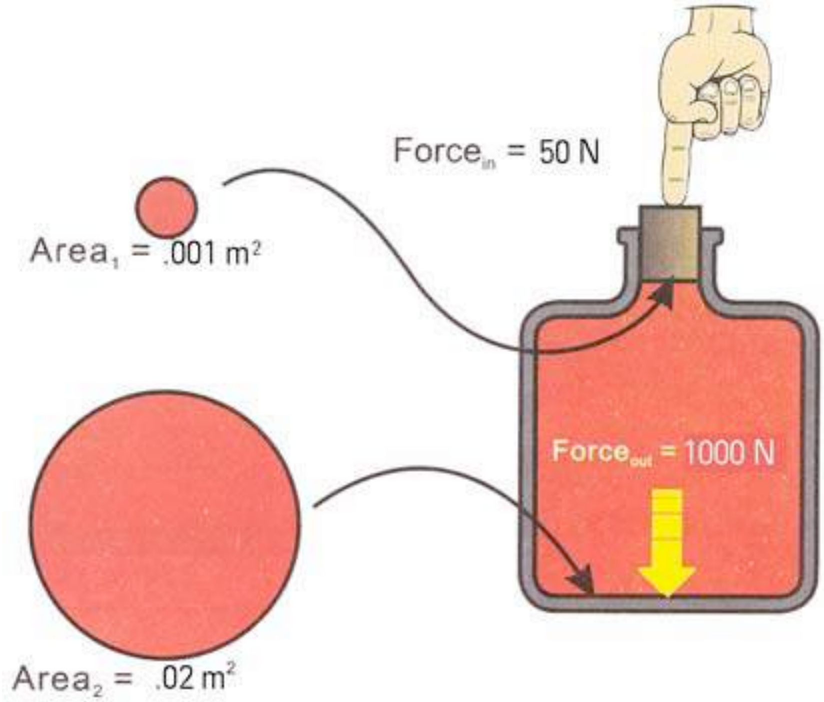


Figure 8 - Pressure, area, force relationship

Figure 8 illustrates the relationship of areas that causes a greater force on the body of the bottle than is applied to the neck. In this illustration, the neck of the bottle has a cross sectional area of .001m2. When the pressure created by this force is transmitted throughout the fluid, it influences all adjacent areas with equal magnitude. It stands to reason that a larger area (a greater number of square inches) will be subjected to a higher combined force.

The bottom of the bottle in Figure 8 has a total area of .02m2 as shown, and the force applied by the liquid is 50N. Therefore, the combined force over the entire bottom area is the sum of 50N acting on each of the .001m2 areas. Because there are 20 areas of .001m2 to make up 0.02m2 and 50N on each, the combined force at the bottom of the bottle is 1000N.

This relationship is represented by the following formula:

Force = Pressure x Area.

This formula allows the Force to be determined and the Pressure and the Area when two of the three are known.

Figure 9

P = Pressure = Force per unit of area.
The unit of measurement of pressure is the Pascal (Pa).
F = Force - which is the push or pull acting upon a body. Force is equal to the pressure times the area (F = P x A).
Force is measured in Newton's (N).
A = Area - which is the extent of a surface. Sometimes the surface area is referred to as effective area. The effective area is the total surface that is used to create a force in the desired direction.
Area is measured in square metres (m2).
The surface area of a circle (as in a piston) is calculated with the formula:
Area = Pi (3.14) times radius-squared.

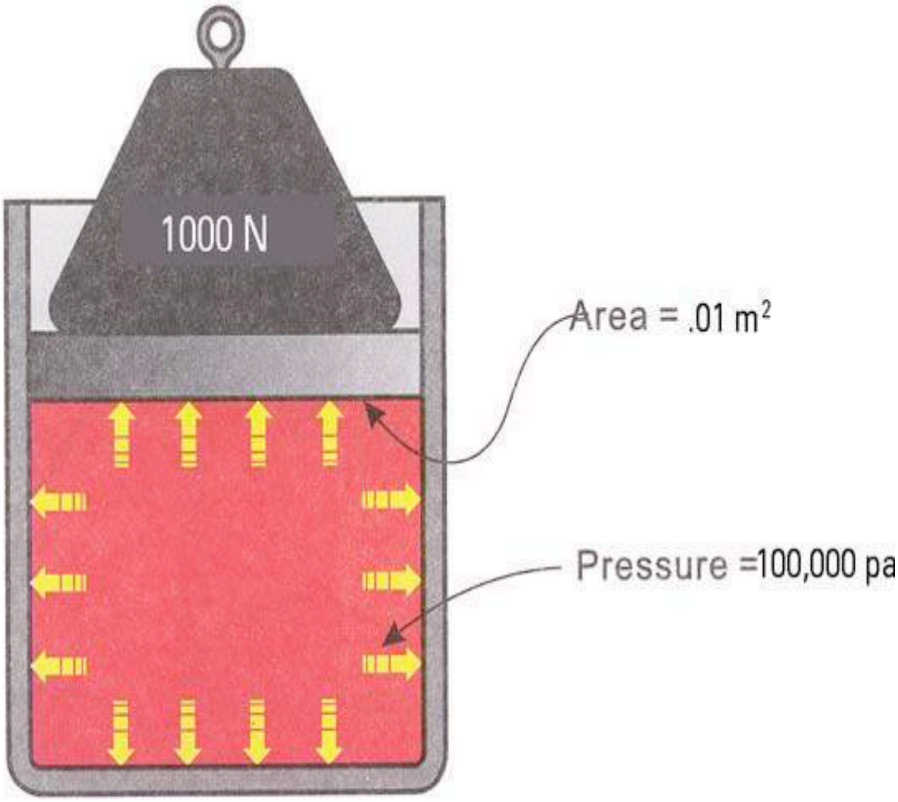


Figure 10 - Pressure created by weight

The same relationship is used to determine the pressure in a fluid resulting from a force applied to it. Figure 10 shows a weight being supported by fluid over a .01m2 area. By rearranging the above formula, the fluid pressure of 100,000Pa can be determined by:

Pressure = Force ÷ Area

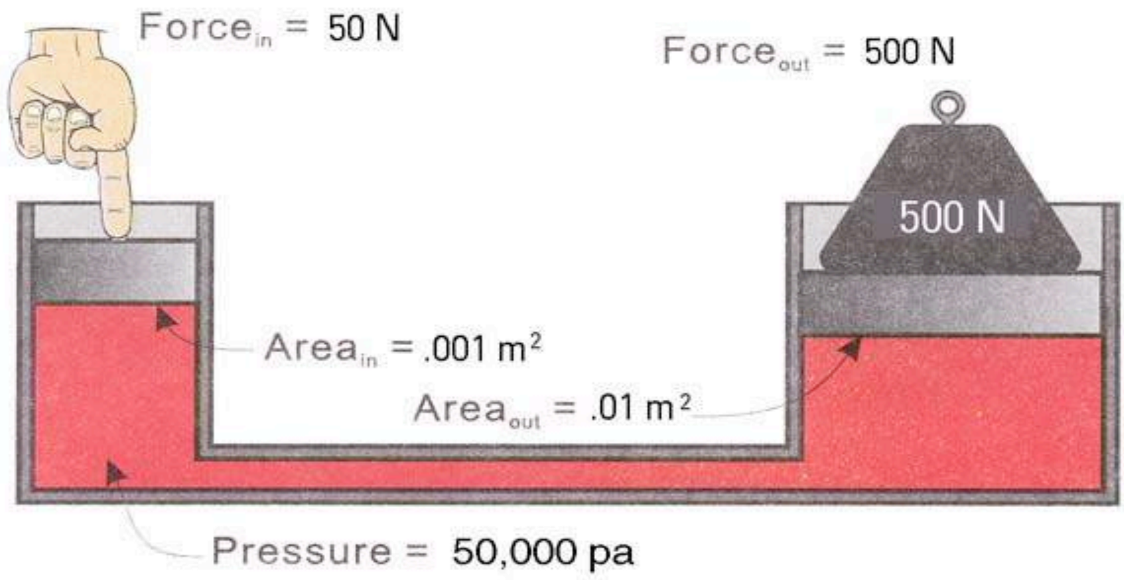


Figure 11 - Transmitting force by fluid

Pascal demonstrated the practical use of his laws with illustrations such as that shown in Figure 11. This diagram shows how, by applying the same principle described above, a small input force applied against a small area can result in a large force by enlarging the output area.
This pressure, applied to the larger output area, will produce a larger force as determined by the formula on the previous page. Thus, a method of multiplying force, much the same as with a pry-bar or lever, is accomplished using fluid as the medium.

- **fluid power advantages**

Multiplying forces is only one advantage of using fluid to transmit power. As the diagram in Figure 11 shows, the forces do not have to be transmitted in a straight line (linearly). Force can be transmitted around corners or in any other non-linear fashion while being amplified. Fluid power is truly a flexible power transmission concept.
Actually, fluid power is the transmission of power from an essentially stationary, rotary source (an electric motor or an internal combustion engine) to a remotely positioned rotary (circular) or linear (straight line) force amplifying device called an actuator. Fluid power can also be looked upon as part of the transformation process of converting a benign form of potential energy (electricity or fuel) to an active mechanical form (linear or rotary force and power).
Once the basic energy is converted to fluid power, other advantages exist:

1. Forces can be easily altered by changing their direction or reversing them.

2. Protective devices can be added that will allow the load operating equipment to stall, but prevent the prime mover (motor or engine) from being overloaded and the equipment components from being excessively stressed.

3. The speed of different components on a machine, such as the boom and winch of a crane, can be controlled independently of each other, as well as independently of the prime mover speed.

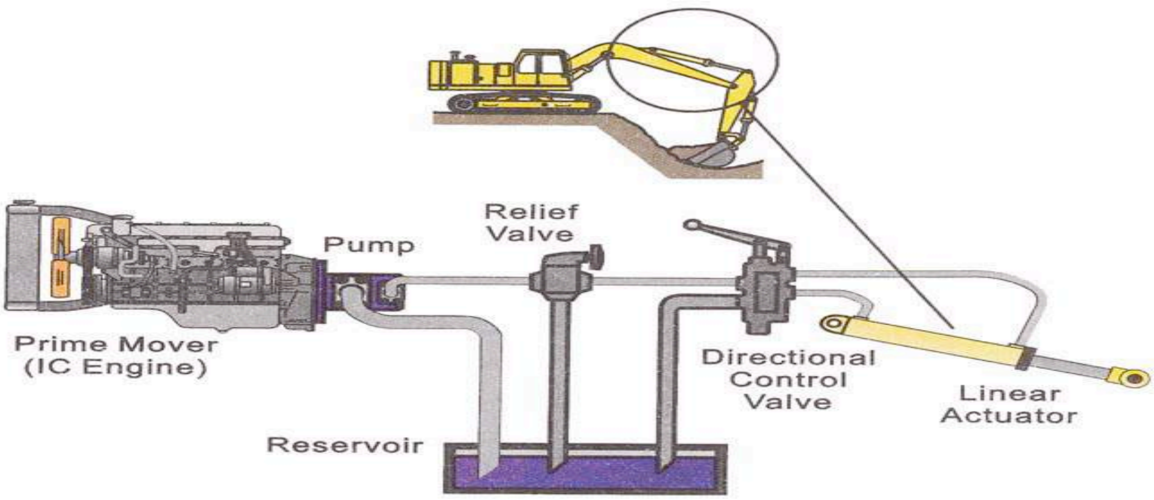


Figure 12 - Simplified Hydraulic Circuit

A complete hydraulic system consists of a reservoir of fluid, a hydraulic pump driven by an internal combustion (IC) engine or an electric motor, a system of valves to control and direct the output flow of the pump, and actuators that apply the forces to conduct the work being performed. Figure 12 is a simplified illustration of these major components.

- **Pressure**

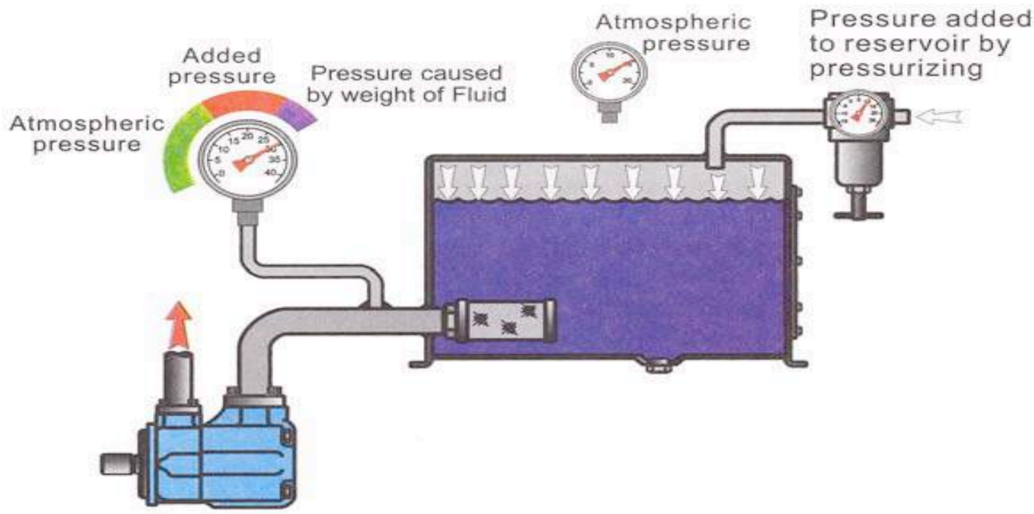


Figure 13 - Pressure at reservoir outlet

The system fluid is forced out of the reservoir into the inlet side of a pump by the sum of several pressures that act on the fluid (Figure 13). The first pressure is the one caused by the weight of the fluid; the second is caused by the weight of the atmosphere; a third may be present if a pressurised reservoir is employed.

- fluid weight

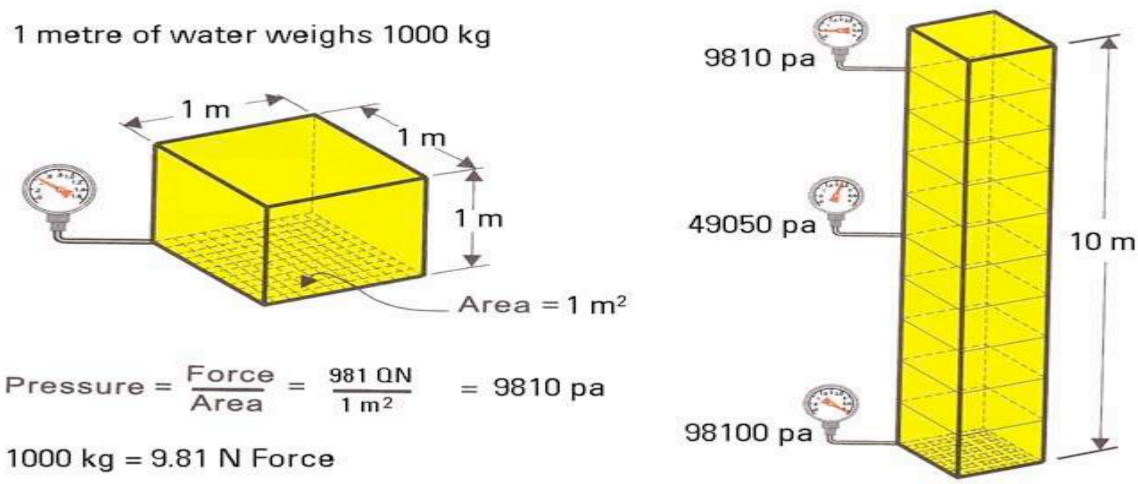


Figure 14 - Pressure caused by weight of water

A cubic meter of water weighs approximately 1000kg. This weight acts downward due to the force of gravity, and causes pressure at the bottom of the fluid. Figure 14 shows how this weight is distributed across the entire bottom of the water volume. In this example, the entire weight is supported by an area measuring one metre by one metre or 1m2.
The pressure of acting at the bottom of 1 cubic metre of water is 9810kPa.
A two metre tall column of water would develop twice as much pressure if spread over the same area (i.e. 19620 Pa).

This is the same pressure felt on eardrums when swimming under water, and experience says that the pressure increases with depth. The pressure can be expressed as follows:

Pressure (Pa) = water depth (m) x 9810 Pa per metre of depth.

Other fluids behave the same as water, the difference being relative to the difference in weight of the fluids. The difference is usually defined by the Specific Gravity of the fluid (SG), which is the ratio of the fluid's weight to the weight of water.

SG = Weight of fluid ÷ Weight of water

A typical specific gravity for oil used in hydraulic systems is approximately 0.92, meaning the weight of the oil is 92% of the weight of water. The relationship of the first formula then becomes:

Pressure (Pa) = Fluid Depth (m) x 9810 Pa/m water x SG.

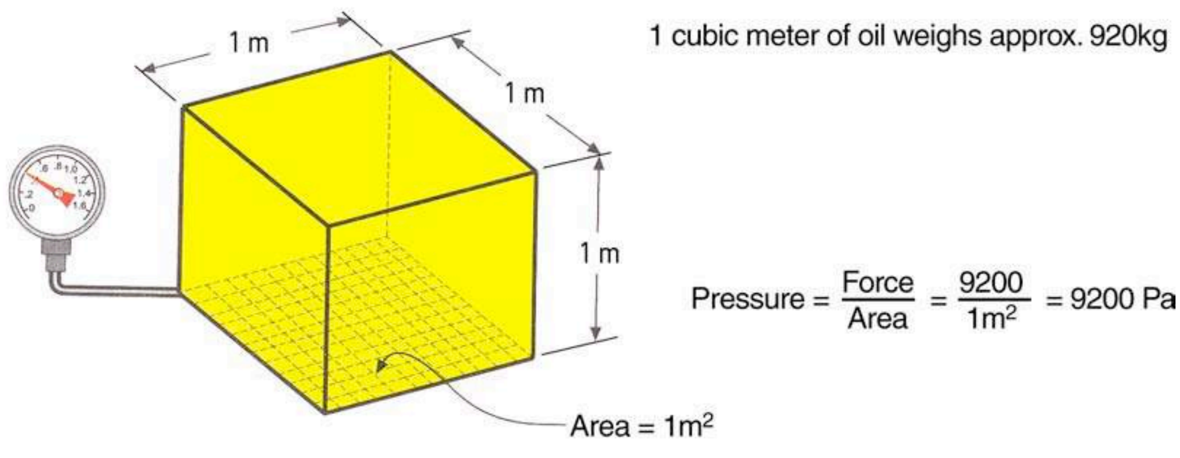


Figure 15 - Pressure caused by the weight of oil

Pure water weighs 1000kg per cubic metre at 4oC, the temperature at which it is most dense. The weight will be slightly less at higher temperatures, but the difference is generally ignored in hydraulic calculations.

Typical hydraulic oil in a reservoir creates a pressure of 9200 Pa per metre of height, as illustrated in Figure 15. This pressure at the bottom of a reservoir helps to push the fluid out of the reservoir and into the inlet of a hydraulic pump, if the pump inlet is below the fluid level.

- **atmospheric pressure**

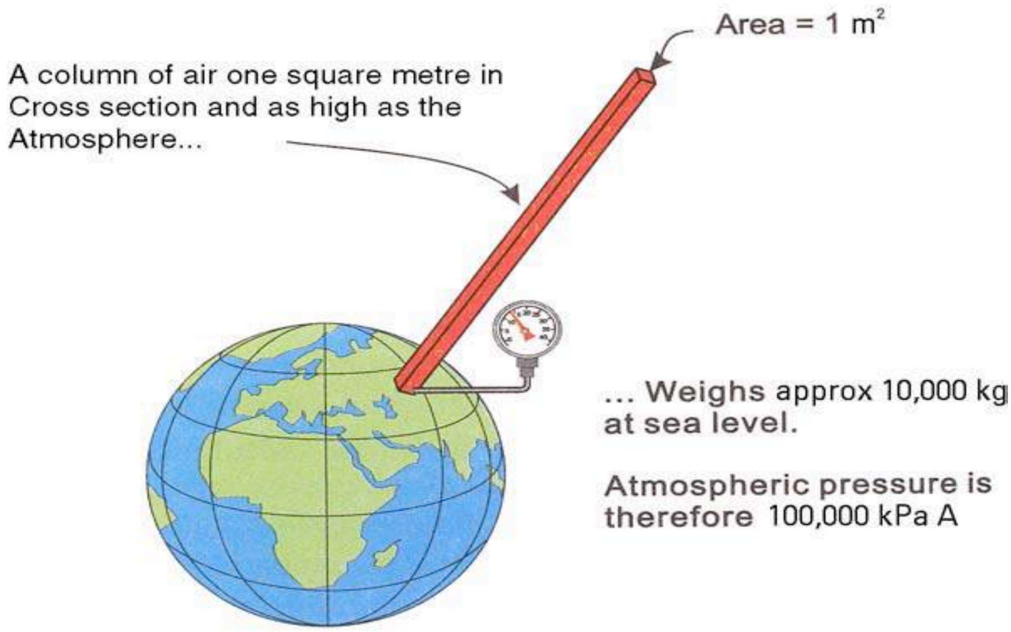


Figure 16 - Weight of air causes atmospheric pressure

Generally air is considered as not having weight. Any reasonable quantity of it is so light that the weight is usually ignored. A column of air measuring one metre by one metre across (1 square metre of area), and extending from the earth's surface at sea level to the extreme of the atmosphere, would actually have a significant weight. This weight, on an average day is approximately 10,000kg, as illustrated in Figure 16. Therefore the pressure that continuously exists at sea level due to the weight of the air above, is 100,000Pa. This is referred to as a standard atmosphere, or the atmospheric pressure on a typical day at sea level which is also known as 1 bar or 1000 mill bars.
This pressure, acting on the reservoir fluid, also helps to push fluid out of the reservoir and into the inlet of a pump.

People are so accustomed to this pressure, and because it exists all the time the pressure under these conditions is considered to be 'zero'. Pressure gauges also read "zero" under these conditions, so the standard atmospheric pressure is referred to as a gauge reading. It is, of course, possible to obtain pressures below this level by removing some of the atmospheric pressure, and this is called a vacuum.

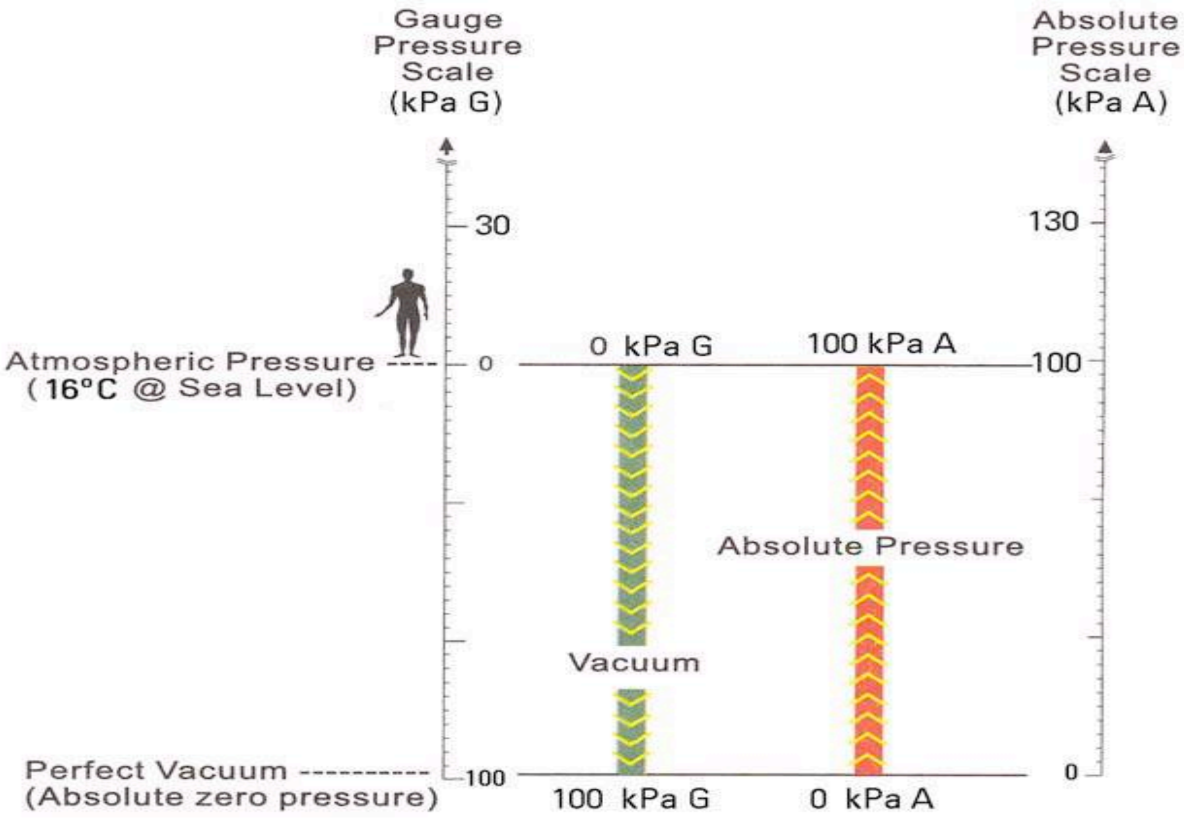


Figure 17 - Gauge and absolute pressure

By removing all of the atmospheric pressure, a “new” zero is derived, and this is called “absolute zero”. Absolute zero is 100 kPa below gauge zero, and is considered a perfect vacuum (Figure 17). There is no pressure below absolute zero.

To differentiate between the two pressures, gauges which read absolute values are labelled as such. This means that the zero for this pressure is absolute zero, and all positive pressure readings start from this level. If the pressure starts at atmospheric pressure as the “zero”, then it is designated gauge pressure. Gauges which read this way are not normally labelled.

- **barometric pressure**

One can see now that as we move above sea level, such as up a mountain, the column of air above us becomes shorter, and thus the weight of the air above us becomes less. The atmospheric pressure is then reduced, and the air is not compressed as much. We recognise this as “thin” air at higher altitudes, and we feel a shortness of breath; the reason being that we get less air into our lungs each time we inhale.

It is important to recognise this phenomenon; at higher altitudes, the atmospheric pressure available to help push fluid out of the bottom of a hydraulic reservoir and into the inlet of a pump is less than at lower altitudes.

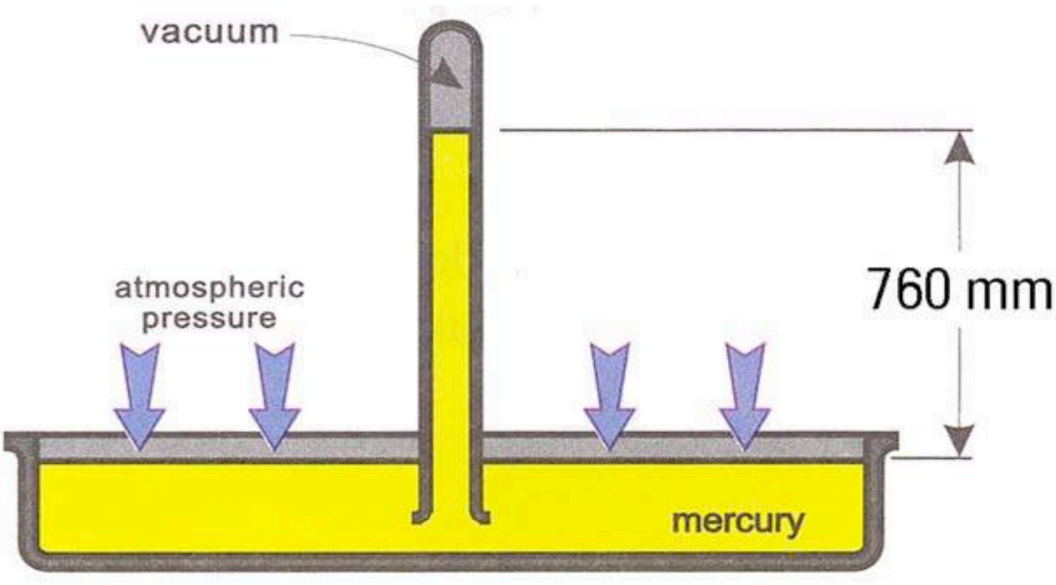


Figure 18 - Barometer principle

Atmospheric pressure is measured by use of a barometer, and this is illustrated in Figure 18. A tube full of mercury is inverted in a pool of mercury as shown. The mercury will fall out of the tube until it reaches a specific height. The space above the mercury in the tube will become a perfect vacuum of 0kPa. The height of the mercury in the tube will correspond to atmospheric pressure, because it is atmospheric pressure that is preventing the mercury from falling the rest of the way out of the tube. At standard atmospheric pressure of 100 kPa mercury will fall in the tube until it reaches a height of 760mm above the pool. As the atmospheric pressure changes (due to climate or altitude change), the height of the mercury will change accordingly.

3. FLUID FLOW

Flow is simply the movement of a quantity of fluid during a period of time. Fluids are confined in hydraulics, such as in hoses, tubes, reservoirs and components, so flow is the movement of a fluid through these confining elements.

Flow is normally designated by the letter “Q”, and is usually expressed in litres-per minute, or LPM, but may also be expressed in cubic-centimetres-per-minute (cm3/min) or per-second (cm3/sec).

In using the above formula the correct units must be used so that they are equal on both sides of the equation. For example, if area is in sq. cm, then velocity must be in cm per second or cm per minute. The flow will then be cubic centimetres (cc) per second or minute.

Flow is basically the velocity of a quantity of fluid past a given point. To visualize this, consider a cross-sectional area of fluid inside a tube. If this cross-sectional “slice” of fluid moved at the rate of one metre in one second, then it would “push” one metre of

Fluid ahead of it every second. The volume of that fluid is the cross sectional area times the length. The time, in this case, is one second. This gives rise to the basic formula for flow in hydraulics:

Flow = Area x Velocity, or Q = A x V.

- **laminar flow**

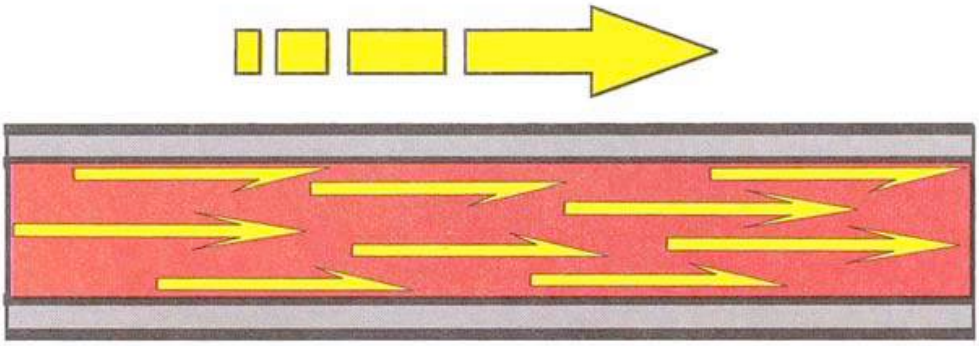


Figure 19 - Laminar flow

We would like to think of flow in a hydraulic system as a smooth transition of fluid from one point to another; all particles of the fluid would be moving parallel to all other particles, and there would be no turmoil within the fluid. This we would call laminar flow (Figure 19), and it is very desirable.

- **turbulent flow**

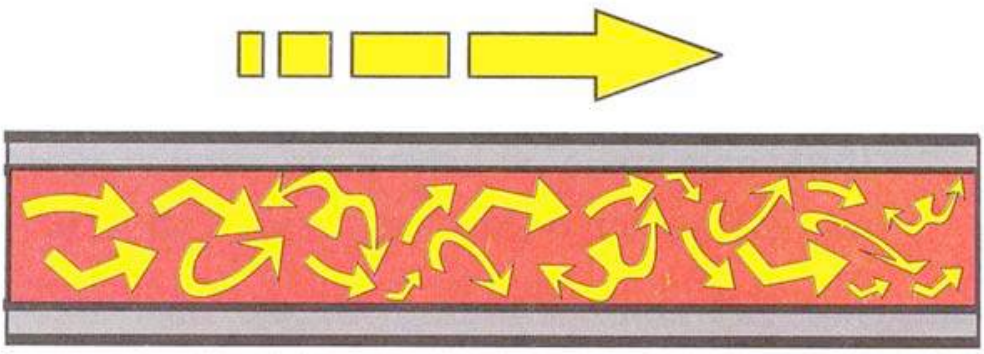


Figure 20 - Turbulent flow

In fact, hydraulic system flow often experiences more turmoil than is desirable. Although the fluid generally move in the direction which is required, it also travels through small conduits, across sharp-edged restrictions, through small orifices, around sharp bends, in fact, through all the places that have a tendency to cause anything but a nice, smooth transition.

Particles of the fluid are travelling helter-skelter among each other (see Figure 20), causing friction and inefficient movement. This type of flow, called turbulent flow, is undesirable and wasteful. Unfortunately, the economic and practical aspects of mobile fluid power result in most flow being in the turbulent variety.

- **pressure drop**

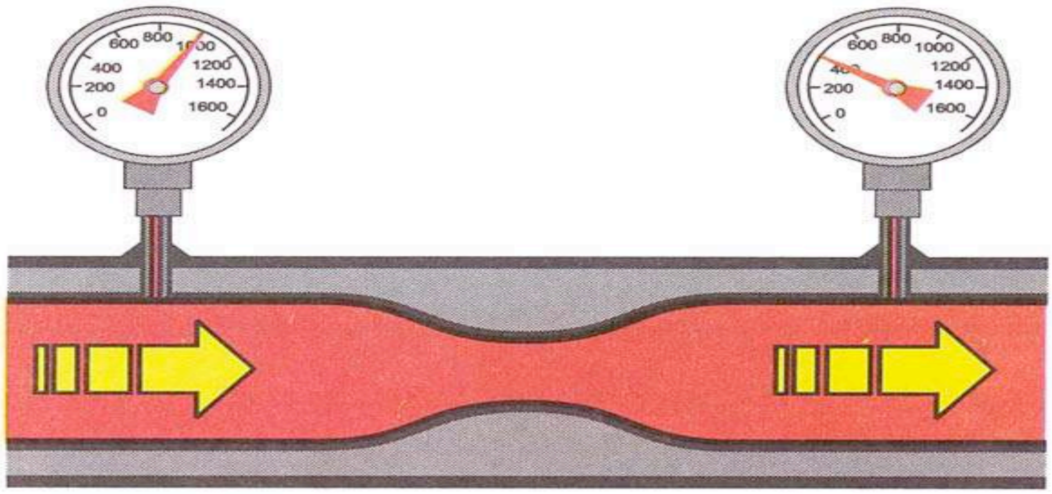


Figure 21 - Flow past an orifice creates a pressure drop

When fluid flows across an orifice, as in Figure 21, it loses some of its energy. This is reflected in a lower pressure at the downstream side of the orifice, as illustrated by the two gauges. The difference between the upstream and downstream pressure is called a pressure drop; it is the drop in pressure caused by the flow and the restriction (orifice).

i. The magnitude of the pressure drop will vary, depending upon:

ii. The rate of flow passing across the orifice

iii. The size of the orifice

iv. The ease with which the fluid will flow (viscosity).

The downstream flow must be the same as the upstream flow in Figure 21, because there is nowhere for the fluid to escape. However, if the pressure in the fluid is lower, then the energy in the fluid is less. A law of physics states that energy cannot be destroyed, therefore the difference in energy must be given off in the form of heat.

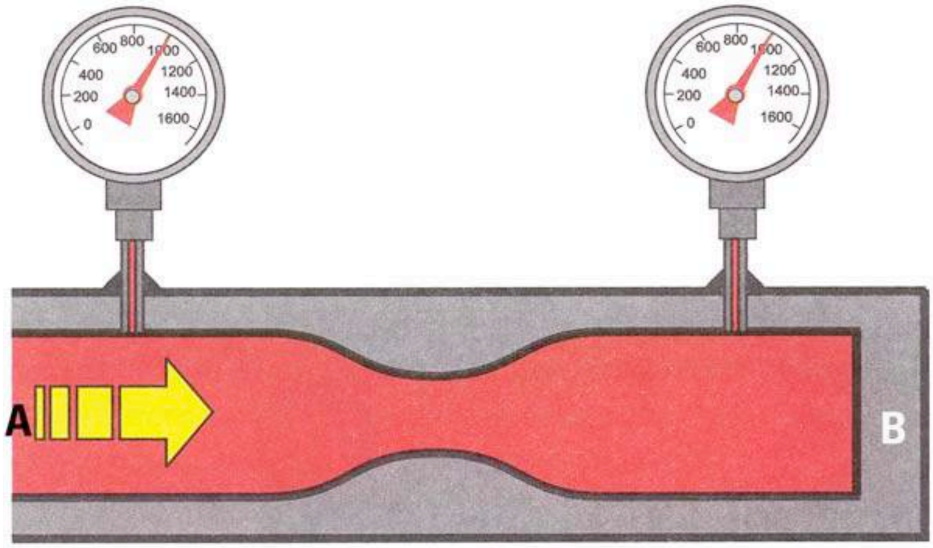


Figure 22 - If there is no flow across an orifice, there is no pressure drop

If the magnitude of the pressure drop is dependent on the amount of flow passing the restriction, then it stands to reason that if there is no flow, there will be no pressure drop. This is demonstrated by Figure 22; there being no flow across the orifice will result in equal pressure on both sides. With no flow and no pressure drop, there will be no heat rejected due to a drop in energy.

This direct relationship between flow and pressure drop is an important consideration in hydraulics; if there is no flow between point A and point B, there will be no pressure drop. Conversely, if there is no difference in pressure between points A and B, there is no fluid flow between these two points.

- **Bernoulli's principle**

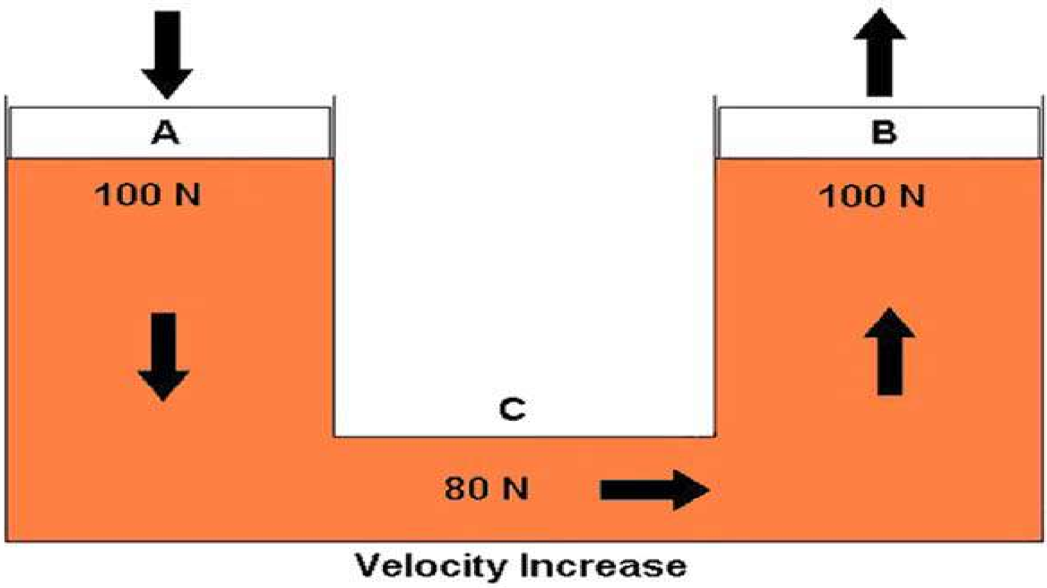


Figure 23

Bernoulli's Principle tells us that the sums of pressure and kinetic energy at various points in a system must be constant, if flow is constant. When a fluid flows through areas of different diameters as shown in Figure 23, there must be corresponding changes in velocity. At the left, the section is large so velocity is low. In the centre, velocity must be increased because the area is smaller. Again, at the right, the area increases to the original size and the velocity again decreases.

Bernoulli proved that the pressure component at C must be less than at A and B because velocity is greater. An increase in velocity at C means an increase in kinetic energy. Kinetic energy can only increase if pressure decrease. At B, the extra kinetic energy has been converted back to pressure and flow decreases. If there is no frictional loss, the pressure at B is equal to the pressure at A.

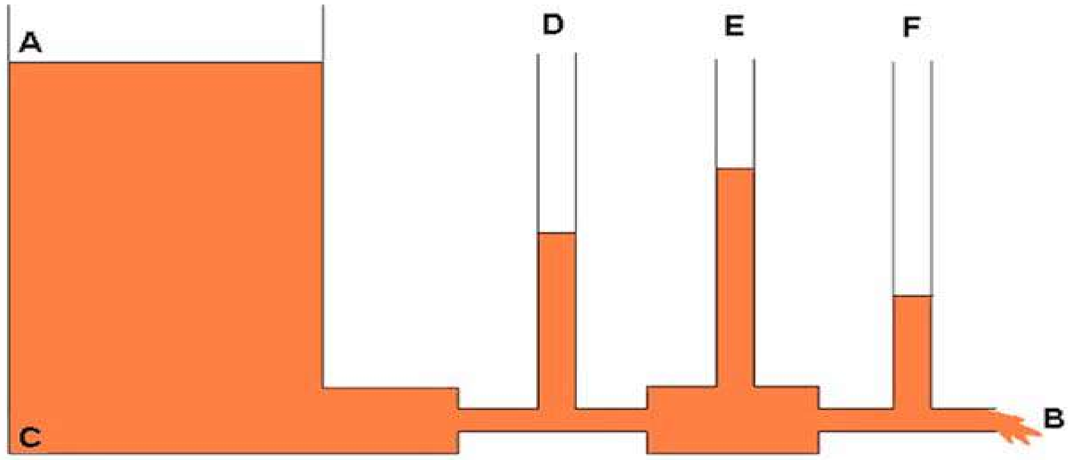


Figure 24

Figure 24 shows the combined effects of friction and velocity changes. Pressure drops from a maximum at C to zero at B. At D, velocity is increased, so the pressure head decreases. At E, the head increases as most of the kinetic energy is given up to pressure energy because velocity is decreased. Again, at F, the head drops as velocity increases.

Put simply, Bernoulli's Principle is indicating that:

i. As flow increases, pressure decreases
ii. As flow decreases, pressure increases

UNIT-2 Different Type of Hydraulic Components and Their symbols.

Objective:

Skill:

At the end of this unit trainees shall be able to

1. Recognize different types of Hydraulics devices and their working principles.

Knowledge:

At the end of this unit trainees shall be able to

1. Demonstrate the working principal of different types of Hydraulic components.
2. Recognize the symbol of different types of hydraulic devices.
3. Build up different type of hydraulic circuits.

Guidelines to Instructor:

Demonstrate the working principles of different types of hydraulic component.

Structure:

1. Basic block diagram of a Hydraulic system.
2. Hydraulic Pump.
3. Control valves.
4. Graphical Representation of Hydraulic Elements.
5. Case Study.

1. BASIC BLOCK DIAGRAM OF A HYDRAULIC SYSTEM.

The hydraulic systems consists a number of parts for its proper functioning. These include storage tank, filter, hydraulic pump, pressure regulator, control valve, hydraulic cylinder, piston and leak proof fluid flow pipelines. The schematic of a simple hydraulic system is shown in figure 5.1.2. It consists of:

- a movable piston connected to the output shaft in an enclosed cylinder
- storage tank
- filter
- electric pump
- pressure regulator
- control valve
- leak proof closed loop piping.

The output shaft transfers the motion or force however all other parts help to control the system. The storage/fluid tank is a reservoir for the liquid used as a transmission media. The liquid used is generally high density incompressible oil. It is filtered to remove dust or any other unwanted particles and then pumped by the hydraulic pump. The capacity of pump depends on the hydraulic system design. These pumps generally deliver constant volume in each revolution of the pump shaft. Therefore, the fluid pressure can increase indefinitely at the dead end of the piston until the system fails. The pressure regulator is used to avoid such circumstances which redirect the excess fluid back to the storage tank. The movement of piston is controlled by changing liquid flow from port A and port B. The cylinder movement is controlled by using control valve which directs the fluid flow. The fluid pressure line is connected to the port B to raise the piston and it is connected to port A to lower down the piston. The valve can also stop the fluid flow in any of the port. The leak proof piping is also important due to safety, environmental hazards and economical aspects. Some accessories such as flow control system, travel limit control, electric motor starter and overload protection may also be used in the hydraulic systems which are not shown in figure 5.1.2.

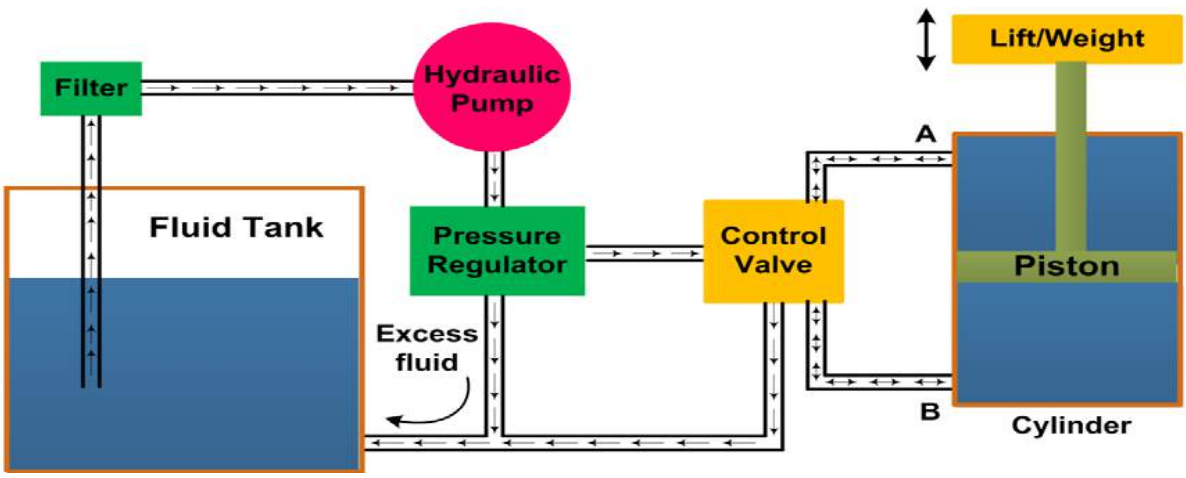


Figure 1- Schematic of hydraulic system

applications of hydraulic systems

The hydraulic systems are mainly used for precise control of larger forces. The main applications of hydraulic system can be classified in five categories:

- **industrial:** Plastic processing machineries, steel making and primary metal extraction applications, automated production lines, machine tool industries, paper industries, loaders, crushes, textile machineries, R & D equipment and robotic systems etc.
- **mobile hydraulics:** Tractors, irrigation system, earthmoving equipment, material handling equipment, commercial vehicles, tunnel boring equipment, rail equipment, building and construction machineries and drilling rigs etc.
- **automobiles:** It is used in the systems like breaks, shock absorbers, steering system, wind shield, lift and cleaning etc.
- **marine applications:** It mostly covers ocean going vessels, fishing boats and navel equipment.
- **aerospace equipment:** There are equipment and systems used for rudder control, landing gear, breaks, flight control and transmission etc. which are used in airplanes, rockets and spaceships.

advantages and disadvantages of hydraulic system

advantages

• The hydraulic system uses incompressible fluid which results in higher efficiency.
• It delivers consistent power output which is difficult in pneumatic or mechanical drive systems.
• Hydraulic systems employ high density incompressible fluid. Possibility of leakage is less in hydraulic system as compared to that in pneumatic system. The maintenance cost is less.
• These systems perform well in hot environment conditions.

disadvantages

• The material of storage tank, piping, cylinder and piston can be corroded with the hydraulic fluid. Therefore one must be careful while selecting materials and hydraulic fluid.
• The structural weight and size of the system is more which makes it unsuitable for the smaller instruments.
• The small impurities in the hydraulic fluid can permanently damage the complete system, therefore one should be careful and suitable filter must be installed.
• The leakage of hydraulic fluid is also a critical issue and suitable prevention method and seals must be adopted.
• The hydraulic fluids, if not disposed properly, can be harmful to the environment.

2. HYDRAULIC PUMP.

These are mainly classified into two categories:

A. Non-positive displacement pumps

B. Positive displacement pumps.

A. non-positive displacement pumps

These pumps are also known as hydro-dynamic pumps. In these pumps the fluid is pressurized by the rotation of the propeller and the fluid pressure is proportional to the rotor speed. These pumps can not withstanding high pressures and generally used for low-pressure and high-volume flow applications. The fluid pressure and flow generated due to inertia effect of the fluid. The fluid motion is generated due to rotating propeller. These pumps provide a smooth and continuous flow but the flow output decreases with increase in system resistance (load). The flow output decreases because some of the fluid slip back at higher resistance. The fluid flow is completely stopped at very large system resistance and thus the volumetric efficiency will become zero. Therefore, the flow rate not only depends on the rotational speed but also on the resistance provided by the system. The important advantages of non-positive displacement pumps are lower initial cost, less operating maintenance because of less moving parts, simplicity of operation, higher reliability and suitability with wide range of fluid etc. These pumps are primarily used for transporting fluids and find little use in the hydraulic or fluid power industries. Centrifugal pump is the common example of non-positive displacement pumps.

B. positive displacement pumps

These pumps deliver a constant volume of fluid in a cycle. The discharge quantity per revolution is fixed in these pumps and they produce fluid flow proportional to their displacement and rotor speed. These pumps are used in most of the industrial fluid power applications. The output fluid flow is constant and is independent of the system pressure (load). The important advantage associated with these pumps is that the high-pressure and low-pressure areas (means input and output region) are separated and hence the fluid cannot leak back due to higher pressure at the outlets. These features make the positive displacement pump most suited and universally accepted for hydraulic systems. The important advantages of positive displacement pumps over non-positive displacement pumps include capability to generate high pressures, high volumetric efficiency, high power to weight ratio, change in efficiency throughout the pressure range is small and wider operating range pressure and speed. The fluid flow rate of these pumps ranges from 0.1 and 15,000 gpm, the pressure head ranges between 10 and 100,000 psi and specific speed is less than 500.

It is important to note that the positive displacement pumps do not produce pressure but they only produce fluid flow. The resistance to output fluid flow generates the pressure. It means that if the discharge port (output) of a positive displacement pump is opened to the atmosphere, then fluid flow will not generate any output pressure above atmospheric pressure. But, if the discharge port is partially blocked, then the pressure will rise due to the increase in fluid flow resistance. If the discharge port of the pump is completely blocked, then an infinite resistance will be generated. This will result in the breakage of the weakest component in the circuit. Therefore, the safety valves are provided in the hydraulic circuits along with positive displacement pumps. Important positive displacement pumps are gears pumps, vane pumps and piston pumps. The details of these pumps are discussed in the following sections.

B.1.) gear pumps

Gear pump is a robust and simple positive displacement pump. It has two meshed gears revolving about their respective axes. These gears are the only moving parts in the pump. They are compact, relatively inexpensive and have few moving parts. The rigid design of the gears and houses allow for very high pressures and the ability to pump highly viscous fluids. They are suitable for a wide range of fluids and offer self-priming performance. Sometimes gear pumps are designed to function as either a motor or a pump. These pump includes helical and herringbone gear sets (instead of spur gears), lobe shaped rotors similar to Roots blowers (commonly used as superchargers), and mechanical designs that allow the stacking of pumps. Based upon the design, the gear pumps are classified as:

- External gear pumps
- Lobe pumps
- Internal gear pumps
- Gerotor pumps

Generally gear pumps are used to pump:

- Petrochemicals: Pure or filled bitumen, pitch, diesel oil, crude oil, lube oil etc.
- Chemicals: Sodium silicate, acids, plastics, mixed chemicals, isocyanates etc.
- Paint and ink
- Resins and adhesives
- Pulp and paper: acid, soap, lye, black liquor, kaolin, lime, latex, sludge etc.
- Food: Chocolate, cacao butter, fillers, sugar, vegetable fats and oils, molasses, animal food etc.

B.1.i) external gear pump

The external gear pump consists of externally meshed two gears housed in a pump case as shown in figure 1. One of the gears is coupled with a prime mover and is called as driving gear and another is called as driven gear. The rotating gear carries the fluid from the tank to the outlet pipe. The suction side is towards the portion whereas the gear teeth come out of the mesh. When the gears rotate, volume of the chamber expands leading to pressure drop below atmospheric value. Therefore the vacuum is created and the fluid is pushed into the void due to atmospheric pressure. The fluid is trapped between housing and rotating teeth of the gears. The discharge side of pump is towards the portion where the gear teeth run into the mesh and the volume decreases between meshing teeth. The pump has a positive internal seal against leakage; therefore, the fluid is forced into the outlet port. The gear pumps are often equipped with the side wear plate to avoid the leakage. The clearance between gear teeth and housing and between side plate and gear face is very important and plays an important role in preventing leakage. In general, the gap distance is less than 10 micro meters. The amount of fluid discharge is determined by the number of gear teeth, the volume of fluid between each pair of teeth and the speed of rotation. The important drawback of external gear pump is the unbalanced side load on its bearings. It is caused due to high pressure at the outlet and low pressure at the inlet which results in slower speeds and lower pressure ratings in addition to reducing the bearing life. Gear pumps are most commonly used for the hydraulic fluid power applications and are widely used in chemical installations to pump fluid with a certain viscosity.`

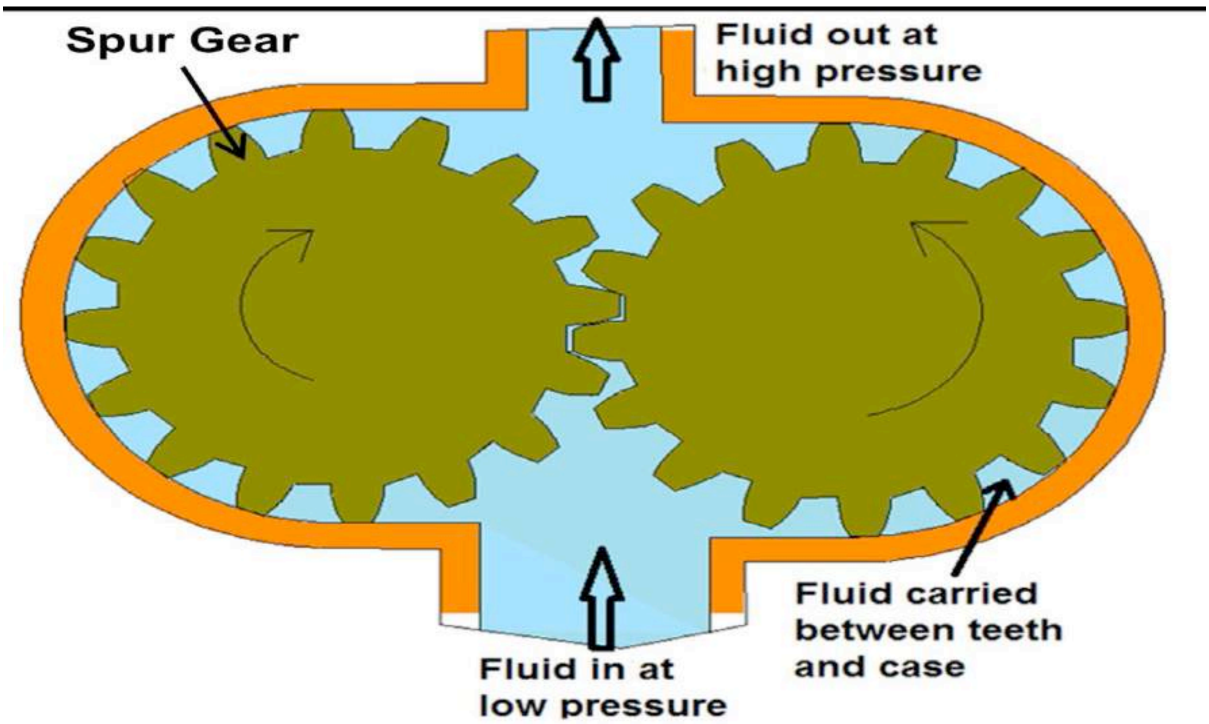


Figure 1- Gear pump

B.1.ii) lobe pump

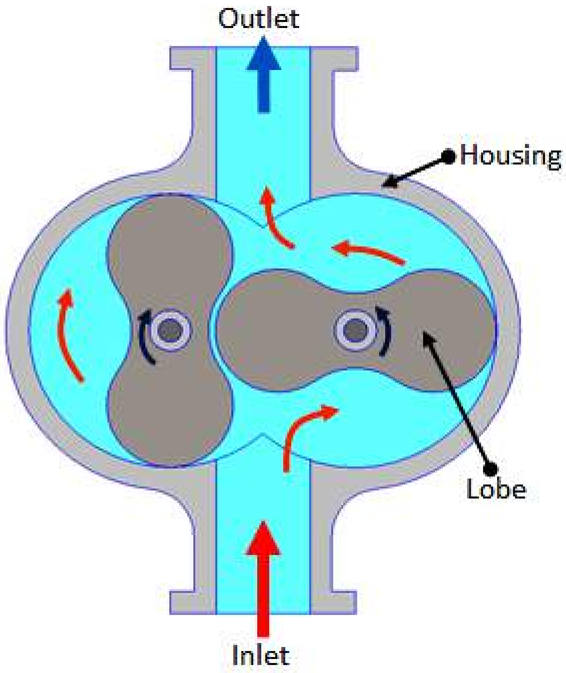


Figure 2- Lobe pump

Lobe pumps work on the similar principle of working as that of external gear pumps. However in Lobe pumps, the lobes do not make any contact like external gear pump (see Figure 2). Lobe contact is prevented by external timing gears located in the gearbox. Similar to the external gear pump, the lobes rotate to create expanding volume at the inlet. Now, the fluid flows into the cavity and is trapped by the lobes. Fluid travels around the interior of casing in the pockets between the lobes and the casing. Finally, the meshing of the lobes forces liquid to pass through the outlet port. The bearings are placed out of the pumped liquid. Therefore the pressure is limited by the bearing location and shaft deflection.

Because of superb sanitary qualities, high efficiency, reliability, corrosion resistance and good clean-in-place and steam-in-place (CIP/SIP) characteristics, Lobe pumps are widely used in industries such as pulp and paper, chemical, food, beverage, pharmaceutical and biotechnology etc. These pumps can handle solids (e.g., cherries and olives), slurries, pastes, and a variety of liquids. A gentle pumping action minimizes product degradation. They also offer continuous and intermittent reversible flows. Flow is relatively independent of changes in process pressure and therefore, the output is constant and continuous.

Lobe pumps are frequently used in food applications because they handle solids without damaging the product. Large sized particles can be pumped much effectively than in other positive displacement types. As the lobes do not make any direct contact therefore, the clearance is not as close as in other Positive displacement pumps. This specific design of pump makes it suitable to handle low viscosity fluids with diminished performance.

Loading characteristics are not as good as other designs, and suction ability is low. High-viscosity liquids require reduced speeds to achieve satisfactory performance. The reduction in speed can be 25% or more in case of high viscosity fluid.

B.1.iii) internal gear pump

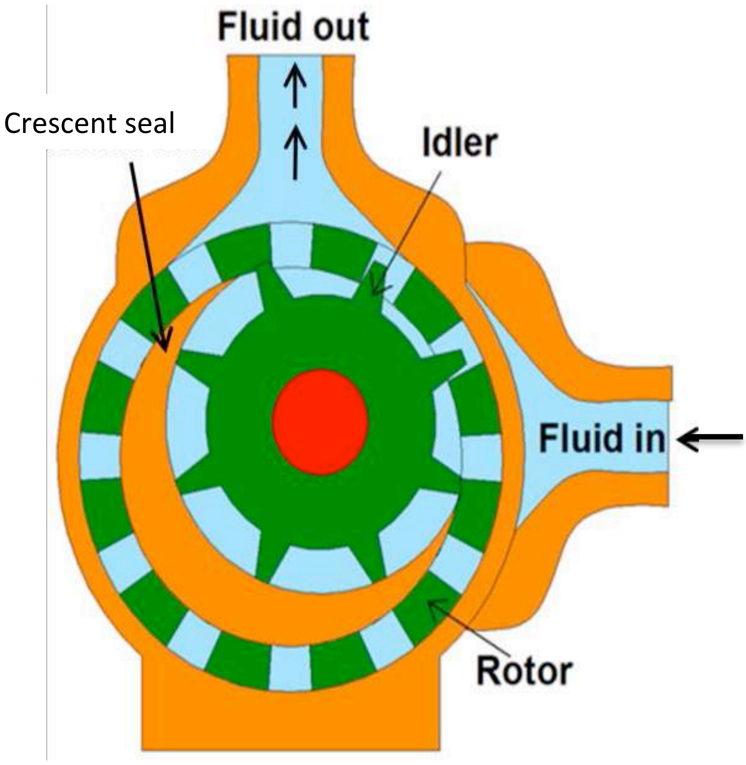


Figure 3- Internal gear pump

Internal gear pumps are exceptionally versatile. They are often used for low or medium viscosity fluids such as solvents and fuel oil and wide range of temperature. This is non-pulsing, self-priming and can run dry for short periods. It is a variation of the basic gear pump.

It comprises of an internal gear, a regular spur gear, a crescent-shaped seal and an external housing. The schematic of internal gear pump is shown in figure 5.2.4. Liquid enters the suction port between the rotor (large exterior gear) and idler (small interior gear) teeth. Liquid travels through the pump between the teeth and crescent. Crescent divides the liquid and acts as a seal between the suction and discharge ports. When the teeth mesh on the side opposite to the crescent seal, the fluid is forced out through the discharge port of the pump. This clearance between gears can be adjusted to accommodate high temperature, to handle high viscosity fluids and to accommodate the wear. These pumps are bi-rotational so that they can be used to load and unload the vessels. As these pumps have only two moving parts and one stuffing box, therefore they are reliable, simple to operate and easy to maintain. However, these pumps are not suitable for high speed and high pressure applications. Only one bearing is used in the pump therefore overhung load on shaft bearing reduces the life of the bearing.

B.1.iv.) Gerotor Pump

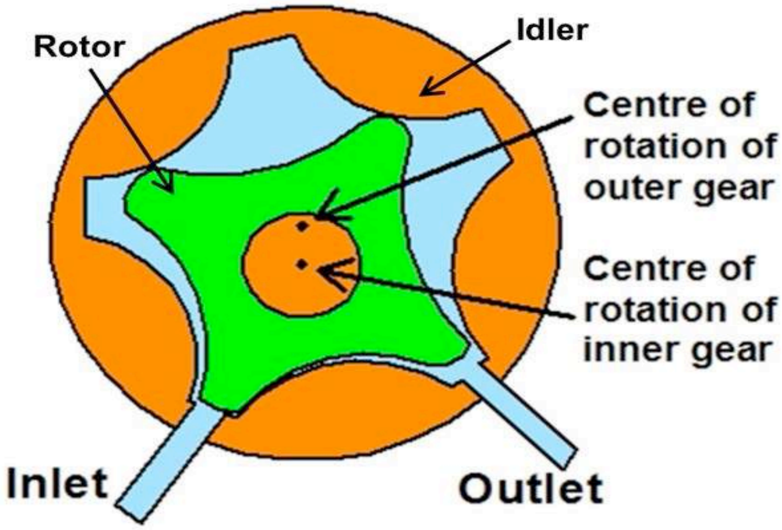


Figure 4- Gerotor pump

Gerotor is a positive displacement pump. The name Gerotor is derived from "Generated Rotor". At the most basic level, a Gerotor is essentially one that is moved via fluid power. Originally this fluid was water, today the wider use is in hydraulic devices. The schematic of Gerotor pump is shown in figure 4 Gerotor pump is an internal gear pump without the crescent. It consists of two rotors viz. inner and outer rotor. The inner rotor has N teeth, and the outer rotor has N+1 teeth. The inner rotor is located off-centre and both rotors rotate. The geometry of the two rotors partitions the volume between them into N different dynamically-changing volumes. During the rotation, volume of each partition changes continuously. Therefore, any given volume first increases, and then decreases. An increase in volume creates vacuum. This vacuum creates suction, and thus, this part of the cycle sucks the fluid. As the volume decreases, compression occurs. During this compression period, fluids can be pumped, or compressed (if they are gaseous fluids).

The close tolerance between the gears acts as a seal between the suction and discharge ports. Rotor and idler teeth mesh completely to form a seal equidistant from the discharge and suction ports. This seal forces the liquid out of the discharge port. The flow output is uniform and constant at the outlets.

The important advantages of the pumps are high speed operation, constant discharge in all pressure conditions, bidirectional operation, less sound in running condition and less maintenance due to only two moving parts and one stuffing box etc. However, the pump is having some limitations such as medium pressure operating range, clearance is fixed, solids can’t be pumped and overhung load on the shaft bearing etc.

B.2.) vane pumps

In the previous lecture we have studied the gear pumps. These pumps have a disadvantage of small leakage due to gap between gear teeth and the pump housing. This limitation is overcome in vane pumps. The leakage is reduced by using spring or hydraulically loaded vanes placed in the slots of driven rotor. Capacity and pressure ratings of a vane pump are generally lower than the gear pumps, but reduced leakage gives an improved volumetric efficiency of around 95%.

Vane pumps are available in a number of vane configurations including sliding vane, flexible vane, swinging vane, rolling vane, and external vane etc. Each type of vane pump has its own advantages. For example, external vane pumps can handle large solids. Flexible vane pumps can handle only the small solids but create good vacuum. Sliding vane pumps can run dry for short periods of time and can handle small amounts of vapour. The vane pumps are known for their dry priming, ease of maintenance, and good suction characteristics. The operating range of these pumps varies from -32 °C to 260 °C.

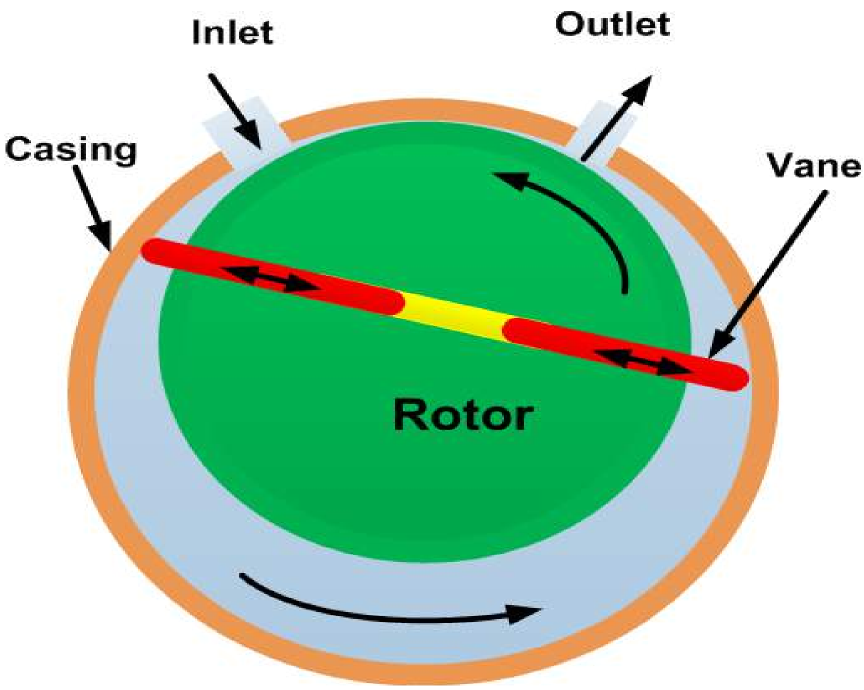


Figure 5 - Schematic of working principle of vane pump

The schematic of vane pump working principle is shown in figure 5 Vane pumps generate a pumping action by tracking of vanes along the casing wall. The vane pumps generally consist of a rotor, vanes, ring and a port plate with inlet and outlet ports. The rotor in a vane pump is connected to the prime mover through a shaft. The vanes are located on the slotted rotor. The rotor is eccentrically placed inside a cam ring as shown in the figure. The rotor is sealed into the cam by two side plates. When the prime mover rotates the rotor, the vanes are thrown outward due to centrifugal force. The vanes track along the ring. It provides a tight hydraulic seal to the fluid which is more at the higher rotation speed due to higher centrifugal force. This produces a suction cavity in the ring as the rotor rotates. It creates vacuum at the inlet and therefore, the fluid is pushed into the pump through the inlet. The fluid is carried around to the outlet by the vanes whose retraction causes the fluid to be expelled. The capacity of the pump depends upon the eccentricity, expansion of vanes, width of vanes and speed of the rotor. It can be noted that the fluid flow will not occur when the eccentricity is zero. These pumps can handle thin liquids (low viscosity) at relatively higher pressure. These pumps can be run dry for a small duration without any failure. These pumps develop good vacuum due to negligible leakage. However, these pumps are not suitable for high speed applications and for the high viscosity fluids or fluids carrying some abrasive particles. The maintenance cost is also higher due to many moving parts. These pumps have various applications for the pumping of following fluids:

- Aerosol and Propellants
- Aviation Service - Fuel Transfer, Deicing
- Auto Industry - Fuels, Lubes, Refrigeration Coolants
- Bulk Transfer of LPG and NH3
- LPG Cylinder Filling
- Alcohols
- Refrigeration - Freon, Ammonia
- Solvents
- Aqueous solutions

B.2.1) unbalanced vane pump

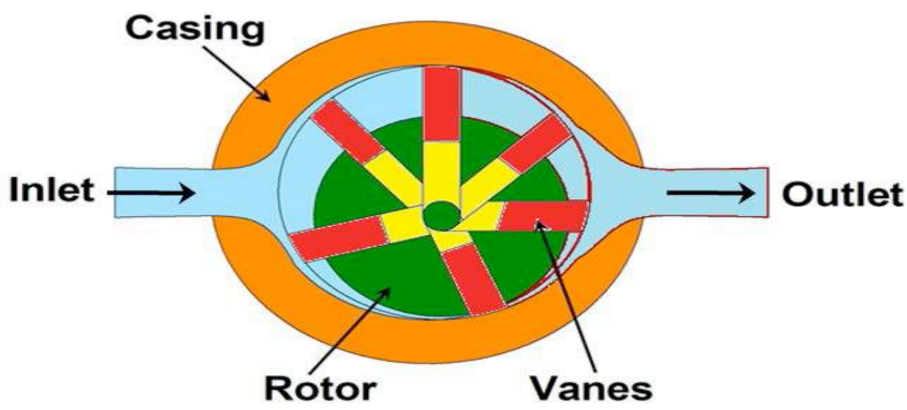


Figure 6- Unbalanced vane pump

In practice, the vane pumps have more than one vane as shown in figure 6. The rotor is offset within the housing, and the vanes are constrained by a cam ring as they cross inlet and outlet ports. Although the vane tips are held against the housing, still a small amount of leakage exists between rotor faces and body sides. Also, the vanes compensate to a large degree for wear at the vane tips or in the housing itself. The pressure difference between outlet and inlet ports creates a large amount of load on the vanes and a significant amount of side load on the rotor shaft which can lead to bearing failure. This type of pump is called as unbalanced vane pump.

B.2.2) balanced vane pump

Figure 5.3.3 shows the schematic of a balanced vane pump. This pump has an elliptical cam ring with two inlet and two outlet ports. Pressure loading still occurs in the vanes but the two identical pump halves create equal but opposite forces on the rotor. It leads to the zero net force on the shaft and bearings. Thus, lives of pump and bearing increase significantly. Also the sounds and vibrations decrease in the running mode of the pump.

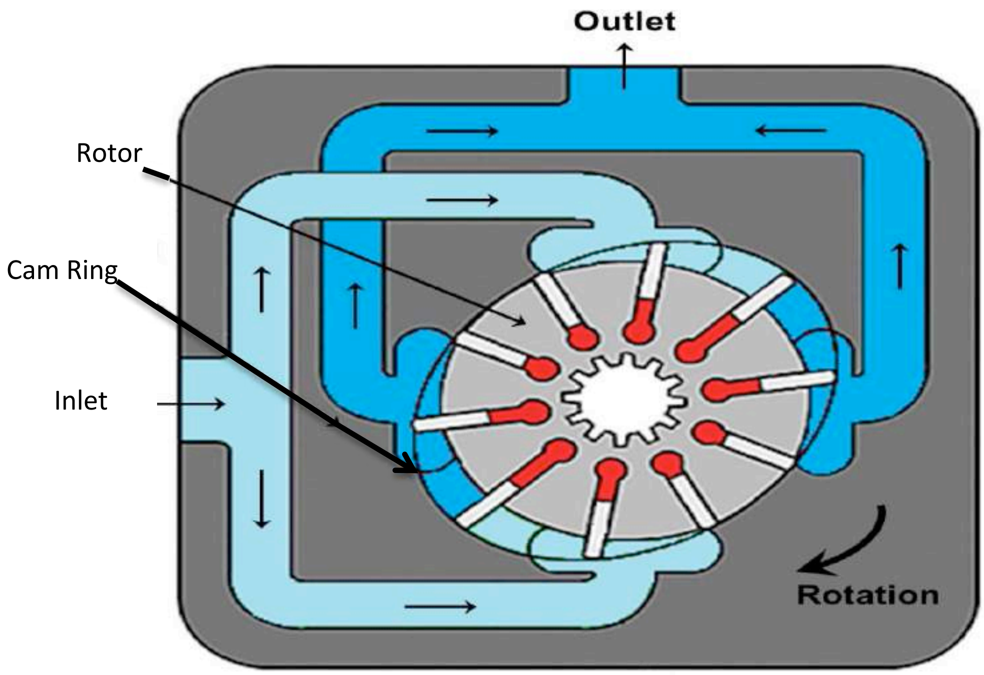


Figure 7- Balanced Vane Pump

B.2.3) Adjustable vane pump

The proper design of pump is important and a challenging task. In ideal condition, the capacity of a pump should be exactly same to load requirements. A pump with larger capacity wastes energy as the excess fluid will pass through the pressure relief valve. It also leads to a rise in fluid temperature due to energy conversion to the heat instead of useful work and therefore it needs some external cooling arrangement. Therefore, the higher capacity pump increases the power consumption and makes the system bulky and costly. Pumps are generally available with certain standard capacities and the user has to choose the next available capacity of the pump. Also, the flow rate from the pump in most hydraulic applications needs to be varying as per the requirements. Therefore, some vane pumps are also available with adjustable capacity as shown in figure 8. This can be achieved by adjusting a positional relationship between rotor and the inner casing by the help of an external controlling screw. These pumps basically consist of a rotor, vanes, cam ring, port plate, thrust bearing for guiding the cam ring and a discharge control screw by which the position of the cam ring relative to the rotor can be varied. In general, the adjustable vane pumps are unbalanced pump type.

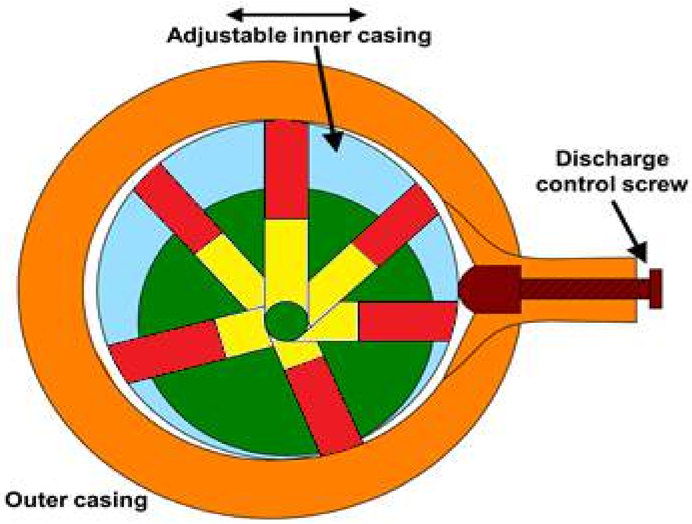


Figure 8- Adjustable vane pump

The amount of fluid that is displaced by a vane pump running at a constant speed is determined by the maximum extension of the vanes and the vanes width. However, for a pump running in operation, the width of vanes cannot be changed but the distance by which the vanes are extended can be varied. This is possible by making a provision for changing the position of the cam ring (adjustable inner casing) relative to the rotor as shown in figure 8. The eccentricity of rotor with respect to the cam ring is adjusted by the movement of the screw. The delivery volume increases with increase in the eccentricity. This kind of arrangement can be used to achieve a variable volume from the pump and is known as variable displacement vane pump.

In general, the adjusted vane pumps are pressure compensated. It means that the discharge is controlled by pre-adjusted value and when the discharge pressure reaches a certain (adjusted) value; the pumping action ceases. This mechanism is accomplished by using a compensating spring to offset the cam ring. Initially, the eccentricity is maximum because the discharge pressure is zero and spring force keeps the cam ring at the extreme right position. As the discharge pressure increases, it acts on the inner contour of the cam ring. It pushes the cam ring towards the left against the spring force and hence the eccentricity reduces and hence the discharge through the pump reduces. When the discharge pressure becomes high enough to overcome the entire spring force; the compensator spring will compress until the zero eccentricity is achieved. In this condition, the pumping action ceases and the fluid flow (except small leakages) does not occur. Therefore, the system pressure can be adjusted by setting the compensator spring. These pumps ensure their own protection against excessive system pressure and do not rely on the safety control devices of the hydraulic system. These pumps are used as energy savings devices and have been used in many applications, including automotive transmissions.

B.3) piston pumps

Piston pumps are meant for the high-pressure applications. These pumps have high-efficiency and simple design and needs lower maintenance. These pumps convert the rotary motion of the input shaft to the reciprocating motion of the piston. These pumps work similar to the four stroke engines. They work on the principle that a reciprocating piston draws fluid inside the cylinder when the piston retracts in a cylinder bore and discharge the fluid when it extends. Generally, these pumps have fixed inclined plate or variable degree of angle plate known as swash plate (shown in Figure 9 and Figure 10). When the piston barrel assembly rotates, the swash plate in contact with the piston slippers slides along its surface. The stroke length (axial displacement) depends on the inclination angle of the swash plate. When the swash plate is vertical, the reciprocating motion does not occur and hence pumping of the fluid does not take place. As the swash plate angle increases, the piston reciprocates inside the cylinder barrel. The stroke length increases with increase in the swash plate angle and therefore volume of pumping fluid increases. During one half of the rotation cycle, the pistons move out of the cylinder barrel and the volume of the barrel increases. During another half of the rotation, the pistons move into the cylinder barrel and the barrel volume decreases. This phenomenon is responsible for drawing the fluid in and pumping it out. These pumps are positive displacement pump and can be used for both liquids and gases. Piston pumps are basically of two types:

i. Axial piston pumps

ii. Radial piston pumps

B.3.i) axial piston pump

Axial piston pumps are positive displacement pumps which converts rotary motion of the input shaft into an axial reciprocating motion of the pistons. These pumps have a number of pistons (usually an odd number) in a circular array within a housing which is commonly referred to as a cylinder block, rotor or barrel. These pumps are used in jet aircraft. They are also used in small earthmoving plants such as skid loader machines. Another use is to drive the screws of torpedoes. In general, these systems have a maximum operating temperature of about 120 °C. Therefore, the leakage between cylinder housing and body block is used for cooling and lubrication of the rotating parts. This cylinder block rotates by an integral shaft aligned with the pistons. These pumps have sub-types as:

a. Bent axis piston pumps
b. Swash plate axial piston pump

B.3.i.a) bent-axis piston pumps

Figure 5.3.5 shows the schematic of bent axis piston pump. In these pumps, the reciprocating action of the pistons is obtained by bending the axis of the cylinder block. The cylinder block rotates at an angle which is inclined to the drive shaft. The cylinder block is turned by the drive shaft through a universal link. The cylinder block is set at an offset angle with the drive shaft. The cylinder block contains a number of pistons along its periphery. These piston rods are connected with the drive shaft flange by ball-and-socket joints. These pistons are forced in and out of their bores as the distance between the drive shaft flange and the cylinder block changes. A universal link connects the block to the drive shaft, to provide alignment and a positive drive.

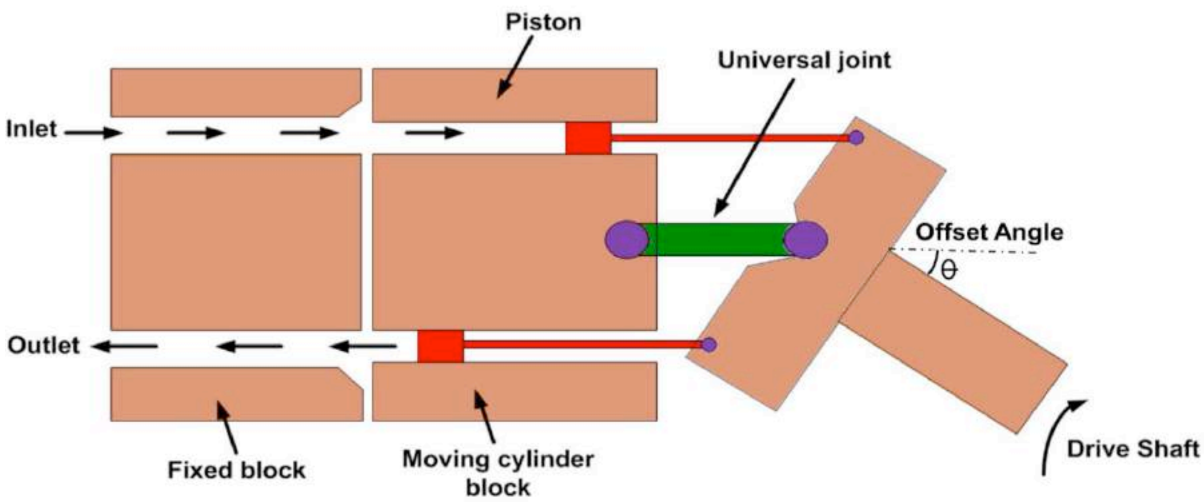


Figure 9- Bent axis piston pump

The volumetric displacement (discharge) of the pump is controlled by changing the offset angle. It makes the system simple and inexpensive. The discharge does not occur when the cylinder block is parallel to the drive shaft. The offset angle can vary from 0° to 40°. The fixed displacement units are usually provided with 23° or 30° offset angles while the variable displacement units are provided with a yoke and an external control mechanism to change the offset angle. Some designs have arrangement of moving the yoke over the centre position to reverse the fluid flow direction. The flow rate of the pump varies with the offset angle θ . There is no flow when the cylinder block centreline is parallel to the drive shaft centreline (offset angle is 0°). The total fluid flow per stroke can be given as:

$V_d = nAD \tan\theta$

The flow rate of the pump can be given as:

$V_d = nADN \tan\theta$

Here $\tan\theta = \frac{S}{D}$

where *S* is the piston stroke, *D* is piston diameter, *n* is the number of pistons, *N* is the speed of pump and *A* is the area of piston.

B.3.i.b) swash plate axial piston pump

A swash plate is a device that translates the rotary motion of a shaft into the reciprocating motion. It consists of a disk attached to a shaft as shown in Figure 10. If the disk is aligned perpendicular to the shaft; the disk will turn along with the rotating shaft without any reciprocating effect. Similarly, the edge of the inclined shaft will appear to oscillate along the shaft's length. This apparent linear motion increases with increase in the angle between disk and the shaft (offset angle). The apparent linear motion can be converted into an actual reciprocating motion by means of a follower that does not turn with the swash plate.

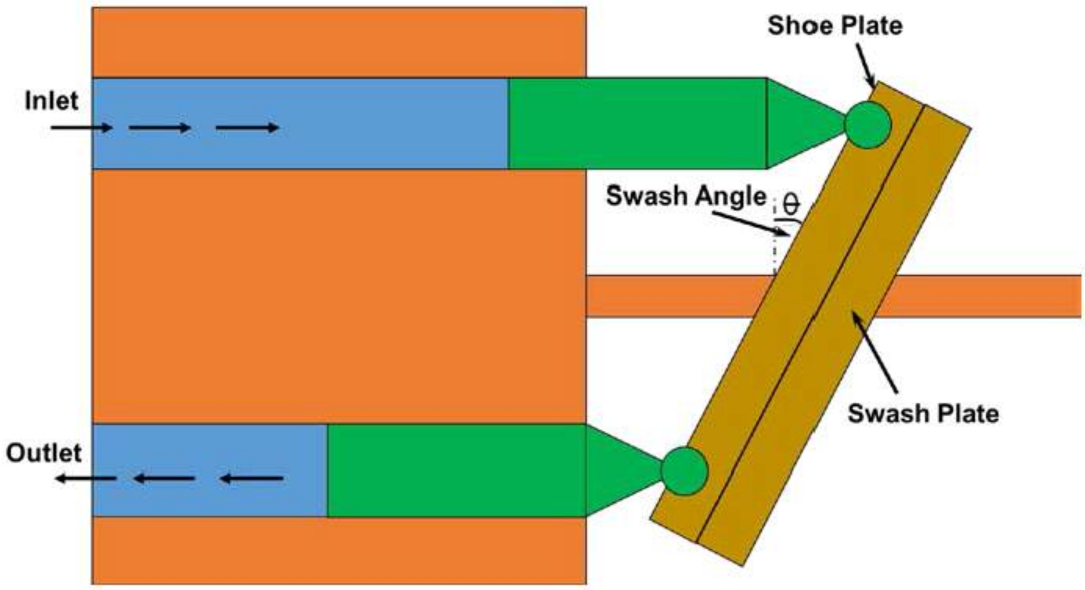


Figure 10- Swash plate piston pump

In swash plate axial piston pump a series of pistons are aligned coaxially with a shaft through a swash plate to pump a fluid. The schematic of swash plate piston pump is shown in Figure 10. The axial reciprocating motion of pistons is obtained by a swash plate that is either fixed or has variable degree of angle. As the piston barrel assembly rotates, the piston rotates around the shaft with the piston shoes in contact with the swash plate. The piston shoes follow the angled surface of the swash plate and the rotational motion of the shaft is converted into the reciprocating motion of the pistons. When the swash plate is perpendicular to the shaft; the reciprocating motion to the piston does not occur. As the swash plate angle increases, the piston follows the angle of the swash plate surface and hence it moves in and out of the barrel. The piston moves out of the cylinder barrel during one half of the cycle of rotation thereby generating an increasing volume, while during other half of the rotating cycle, the pistons move into the cylinder barrel generating a decreasing volume. This reciprocating motion of the piston results in the drawing in and pumping out of the fluid. Pump capacity can be controlled by varying the swash plate angle with the help of a separate hydraulic cylinder. The pump capacity (discharge) increases with increase in the swash plate angle and vice-versa. The cylinder block and the drive shaft in this pump are located on the same centreline. The pistons are connected through shoes and a shoe plate that bears against the swash plate. These pumps can be designed to have a variable displacement capability. It can be done by mounting the swash plate in a movable yoke. The swash plate angle can be changed by pivoting the yoke on pintles.

B.3.ii.) radial piston pump

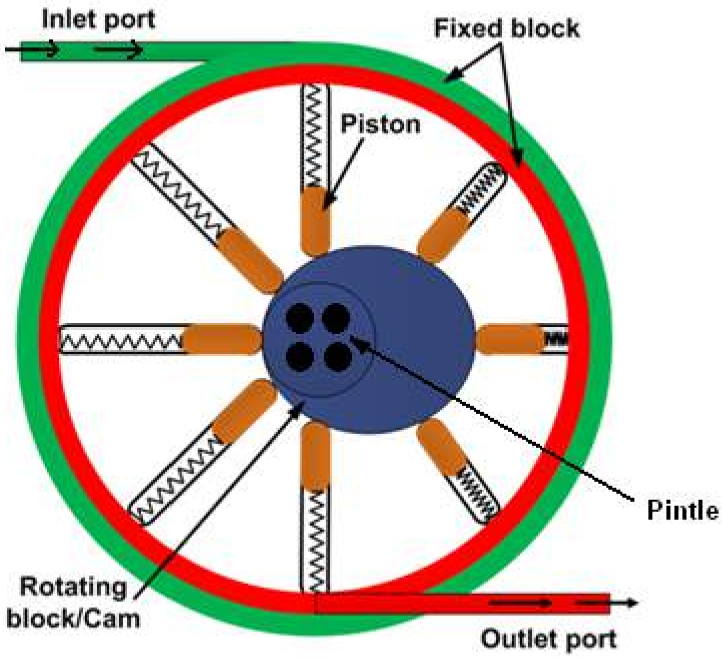


Figure 11- Radial piston pump

The typical construction of radial piston pump is shown in Figure 11. The piston pump has pistons aligned radially in a cylindrical block. It consists of a pintle, a cylinder barrel with pistons and a rotor containing a reaction ring. The pintle directs the fluid in and out of the cylinder. Pistons are placed in radial bores around the rotor. The piston shoes ride on an eccentric ring which causes them to reciprocate as they rotate. The eccentricity determines the stroke of the pumping piston. Each piston is connected to inlet port when it starts extending while it is connected to the outlet port when start retracting. This connection to the inlet and outlet port is performed by the timed porting arrangement in the pintle. For initiating a pumping action, the reaction ring is moved eccentrically with respect to the pintle or shaft axis. As the cylinder barrel rotates, the pistons on one side travel outward. This draws the fluid in as the cylinder passes the suction port of the pintle. It is continued till the maximum eccentricity is reached. When the piston passes the maximum eccentricity, pintle is forced inwards by the reaction ring. This forces the fluid to flow out of the cylinder and enter in the discharge (outlet) port of the pintle.

The radial piston pump works on high pressure (up to 1000 bar). It is possible to use the pump with various hydraulic fluids like mineral oil, biodegradable oil, HFA (oil in water), HFC (water-glycol), HFD (synthetic ester) or cutting emulsion. This is because the parts are hydrostatically balanced. It makes the pump suitable for the many applications such as machine tools (displace of cutting emulsion, supply for hydraulic equipment like cylinders), high pressure units (overload protection of presses), test rigs, automotive sector (automatic transmission, hydraulic suspension control in upper-class cars), plastic (powder injection mouldings) and wind energy etc.

3.) CONTROL VALVES

In a hydraulic system, the hydraulic energy available from a pump is converted into motion and force by means of an actuator. The control of these mechanical outputs (motion and force) is one of the most important functions in a hydraulic system. The proper selection of control selection ensures the desired output and safe function of the system. In order to control the hydraulic outputs, different types of control valves are required. It is important to know various types of control valves and their functions. This not only helps to design a proper hydraulic system but also helps to discover the innovative ways to improve the existing systems. In this lecture and next few lectures, various types of valves will be discussed.

There are basically three types of valves employed in hydraulic systems:

1. Directional control valves
2. Flow control valves
3. Pressure relief valves

1. Directional control valves

Directional control valves are used to control the distribution of energy in a fluid power system. They provide the direction to the fluid and allow the flow in a particular direction. These valves are used to control the start, stop and change in direction of the fluid flow. These valves regulate the flow direction in the hydraulic circuit. These control valves contain ports that are external openings for the fluid to enter and leave. The number of ports is usually identified by the term 'way'. For example, a valve with four ports is named as four-way valve. The fluid flow rate is responsible for the speed of actuator (motion of the output) and should controlled in a hydraulic system. This operation can be performed by using flow control valves. The pressure may increase gradually when the system is under operation. The pressure control valves protect the system by maintaining the system pressure within the desired range. Also, the output force is directly proportional to the pressure and hence, the pressure control valves ensure the desired force output at the actuator.

Directional control valves can be classified in the following manner:

1. Type of construction:
   - Check valves
   - Spool valves
2. Number of ports:
   - Two- way valves
   - Three – way valves
   - Four- way valves.
3. Number of switching position:
   - Two – position
   - Three - position

1.1 Type of construction

1.1.1 Check Valves

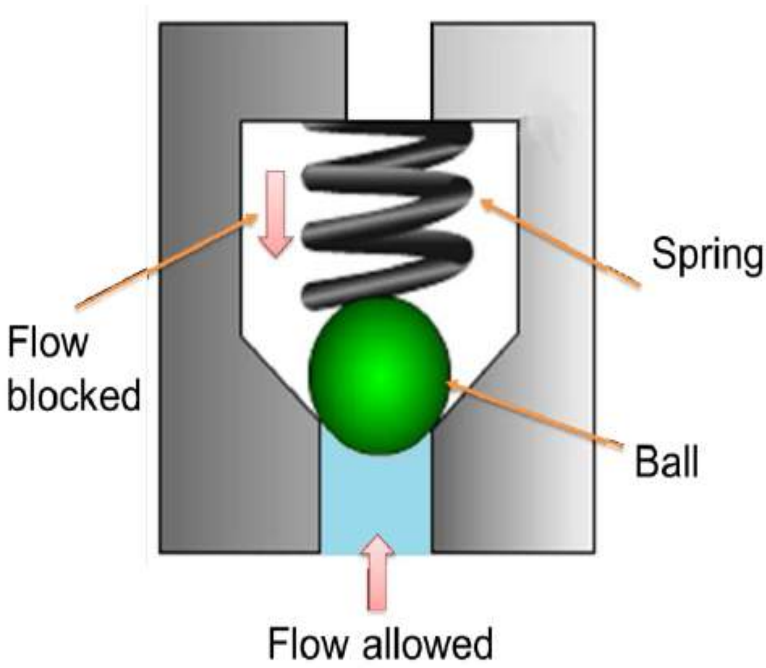


Figure 12- Inline check valve

These are unidirectional valves and permit the free flow in one direction only. These valves have two ports: one for the entry of fluid and the other for the discharge. They are consists of a housing bore in which ball or poppet is held by a small spring force. The valve having ball as a closing member is known as ball check valve. The various types of check valves are available for a range of applications. These valves are generally small sized, simple in construction and inexpensive. Generally, the check valves are automatically operated. Human intervention or any external control system is not required. These valves can wear out or can generate the cracks after prolonged usage and therefore they are mostly made of plastics for easy repair and replacements.

An important concept in check valves is the cracking pressure. The check valve is designed for a specific cracking pressure which is the minimum upstream pressure at which the valve operates. The simplest check valve is an inline check valve as shown in Figure 12. The ball is held against the valve seat by a spring force. It can be observed from the figure that the fluid flow is not possible from the spring side but the fluid from opposite side can pass by lifting the ball against. However, there is some pressure drop across the valve due to restriction by the spring force. Therefore these valves are not suitable for the application of high flow rate. When the operating pressure increases the valve becomes more tightly seated in this design.

The advantages of the poppet valves include no leakage, long life and suitability with high pressure applications. These valves are commonly used in liquid or gel mini-pump dispenser spigots, spray devices, some rubber bulbs for pumping air, manual air pumps, and refillable dispensing syringes. Sometimes, the right angle check valve as shown in Figure 13 is used for the high flow rate applications. The pressure drop is comparatively less in right angle check valve.

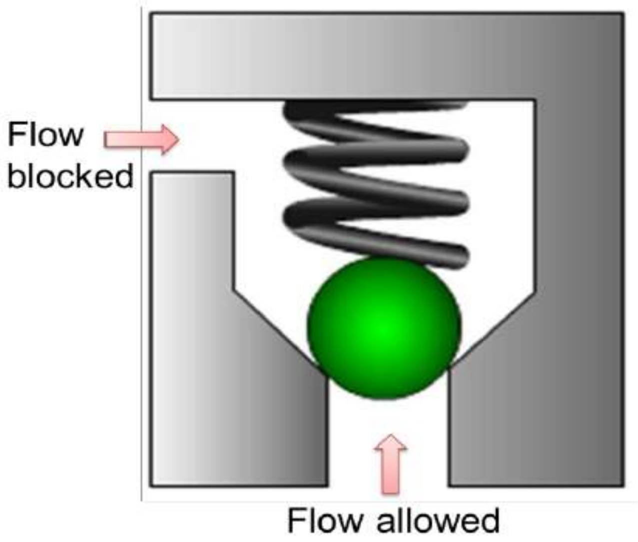


Figure 13 - Right angle check valve

When the closing member is not a ball but a poppet energized by a spring is known as poppet valve. The typical poppet valve is shown in Figure 14. Some valves are meant for an application where free flow is required in one direction and restricted flow required in another direction. These types of valves are called as restriction check valve (see Figure 14). These valves are used when a direction sensitive flow rate is required. For example, the different actuator speeds are required in both the directions. The flow adjustment screw can be used to set the discharge (flow rate) in the restricted direction.

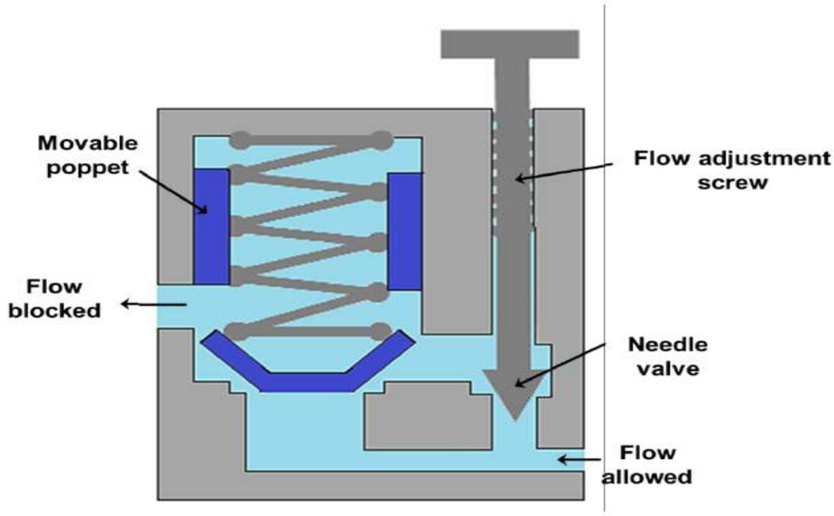


Figure 14 - Restriction check valve

Another important type of check valve known as pilot operated check valve which is shown in figure 15. The function of the pilot operated check valve is similar to a normal check valve unless it gets an extra pressure signal through a pilot line. Pilot allows free flow in one direction and prevents the flow in another direction until the pilot pressure is applied. But when pilot pressure acts, the poppet opens and the flow is blocked from both the sides. These valves are used to stop the fluid suddenly.

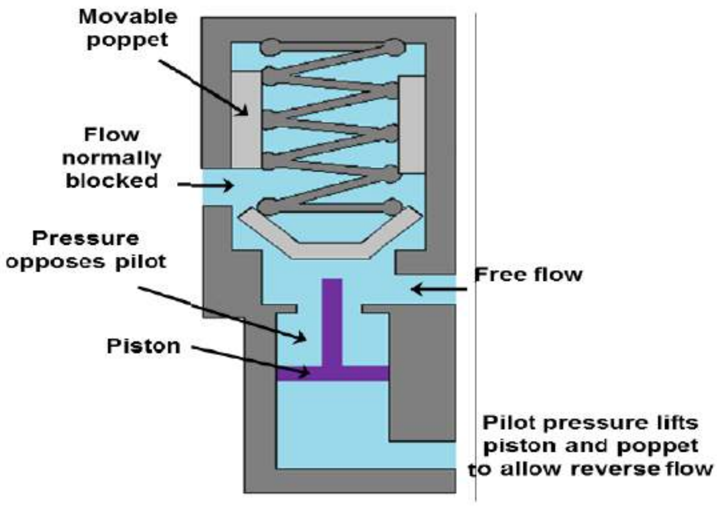


Figure 15 Pilot operated check valve

1.1.2 Spool valve

The spool valves derive their name from their appearance. It consists of a shaft sliding in a bore which has large groove around the circumference. This type of construction makes it look like a spool. The spool is sealed along the clearance between moving spool and housing (valve body). The quality of seal or the amount of leakage depends on the amount of clearance, viscosity of fluid and the level of the pressure. The grooves guide the fluid flow by interconnecting or blocking the holes (ports). The spool valves are categorized according to the number of operating positions and the way hydraulic lines interconnections. One of the simplest two way spool valve is shown in Figure 16. The standard terms are referred as Port 'P' is pressure port, Port 'T' is tank port and Port 'A' and Port 'B' are the actuator (or working) ports. The actuators can move in forward or backward direction depending on the connectivity of the pressure and tank port with the actuators port.

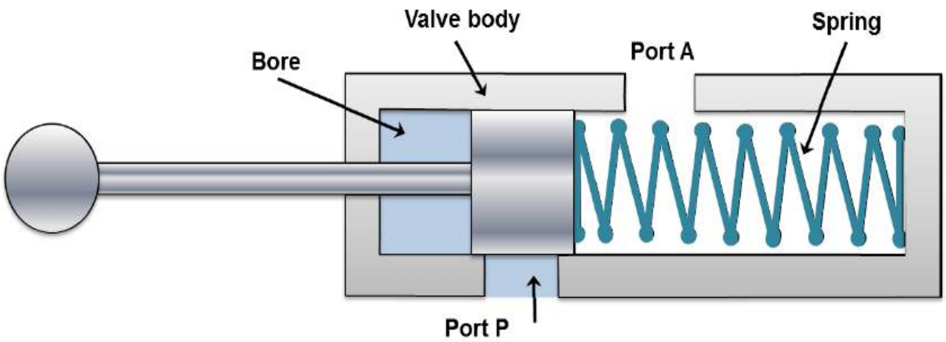


Figure 16 – Valve Closed

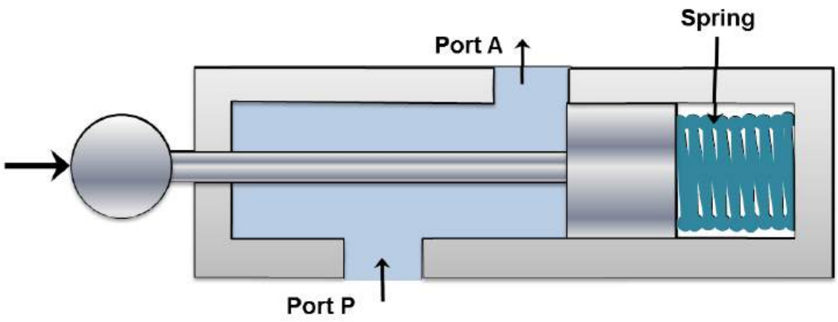


Figure 17 - Valve opened by actuation

1.2 Number of ports

1.2.1 Two way valves

Two way valves have only two ports as shown in Figure 16 and Figure 17. These valves are also known as on-off valves because they allow the fluid flow only in direction. Normally, the valve is closed. These valves are available as normally open and normally closed function. These are the simplest type of spool valves. When actuating force is not applied to the right, the port P is not connected with port A as shown in figure 16. Therefore, the actuation does not take place. Similarly, Figure 17 shows the two-way spool valve in the open condition. Here, the pressure port P is connected with the actuator port A.

1.2.2 Three way valves

When a valve has one pressure port, one tank port and one actuating port as shown in Figures 18 and 19, it is known as three way valve. In this valve, the pressure port pressurizes one port and exhausts another one. As shown in figures, only one actuator port is opened at a time. In some cases a neutral position is also available when both the ports are blocked. Generally, these valves are used to operate single acting cylinders.

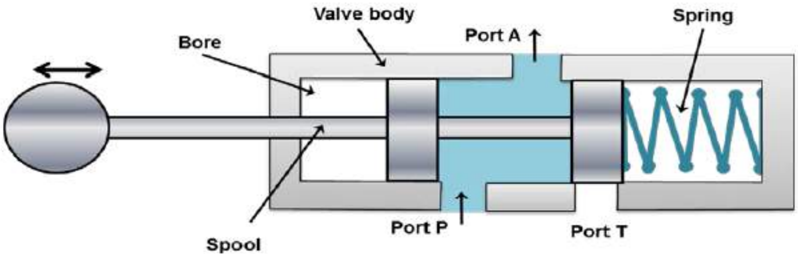


Figure 18- Three way valve: P to A connected and T is blocked

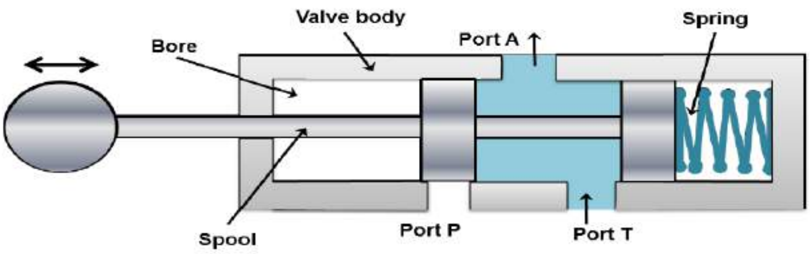


Figure 19- Three way valve in closed position

1.2.3 Four way valves

Figure 20 shows a four-way valve. It is generally used to operate the cylinders and fluid motors in both the directions. The four ways are: pump port P, tank port T, and two working ports A and B connected to the actuator. The primary function of a four way valve is to pressurize and exhaust two working ports A and B alternatively.

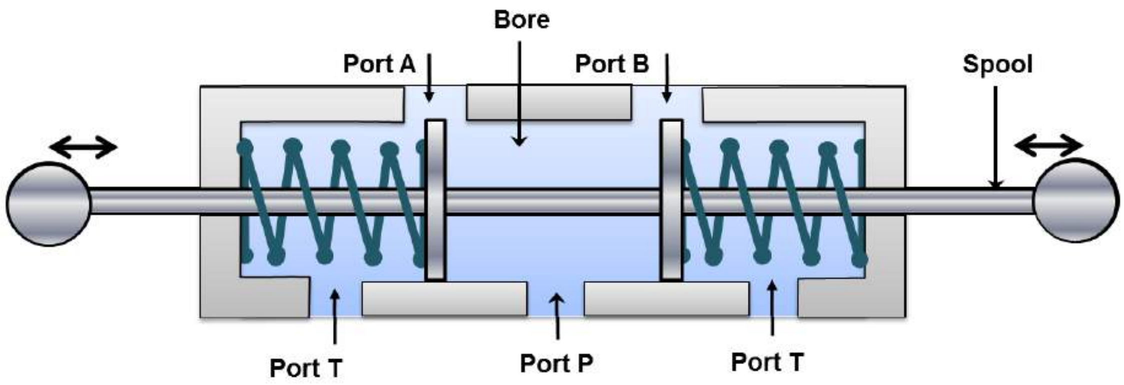


Figure 20- Three position four way valve in open centre mode

1.3 classification of control valve according to number/ways of switching position

1.3.1 Three position four way (3/4) valves

Three position four way (3/4) valves are used in double-acting cylinders to perform advance, hold and return operation to the piston. Figures 21 and 22 show three position four way valves. These types of valves have three switching positions. They have a variety of possible flow path configurations but have identical flow path configuration. When the cantered path is actuated, port A and B are connected with both the ports P and T respectively. In this case, valve is not active because all the ports are open to each other. The fluid flows to the tank at atmospheric pressure. In this position work cannot be done by any part of the system. This configuration helps to prevent heat build-up.

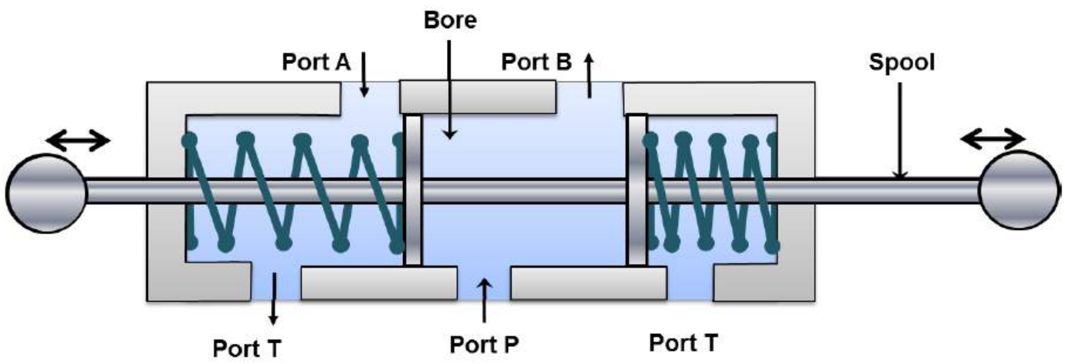


Figure 21- Three position four way valve: P to B and A to T

When left end (port B) is actuated, the port P is connected with ports B and T is connected with port A as shown in Figure 21. Similarly, when the right end is actuated the port P is connected to A and working port B is connected to port T as shown in Figure 22. The three position valves are used when the actuator is needed to stop or hold at some intermediate position. It can also be used when the multiple circuits or functions are accomplished from one hydraulic power source.

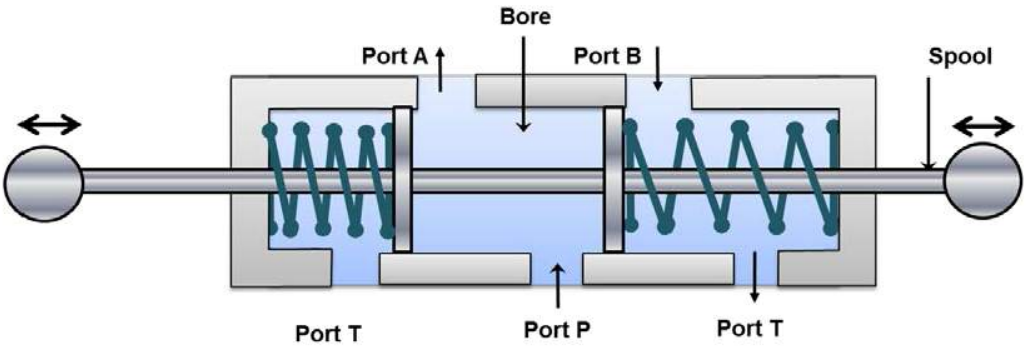


Figure 22- Three position four way valve: P to A and B to T

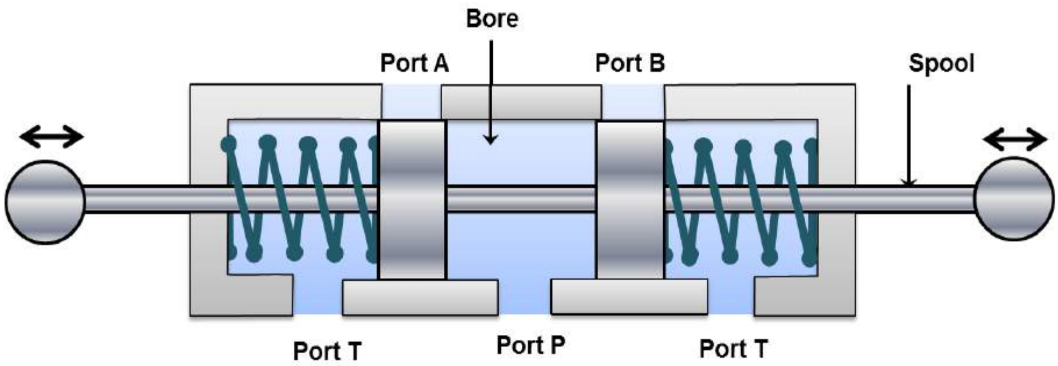


Figure 23- Three position four way valve: closed centre

Figure 23 shows a three position four way valve in the closed centre position. The working of the valve is similar to open centre DCV. In closed centre DCV all user ports (port A and port B) are closed. Therefore, these ports are hydraulically locked and the actuator cannot be moved by the external load. The pumped fluid flows through the relief valve. The pump works under the high pressure condition which not only wastes the pump power but also causes wear of the pump parts. The fluid temperature also rises due to heat generation by the pump energy transformation. The increase in fluid temperature may lead to the oxidation and viscosity drop of the fluid. The oxidation and viscosity drop reduces the pump life and leakage in the system.

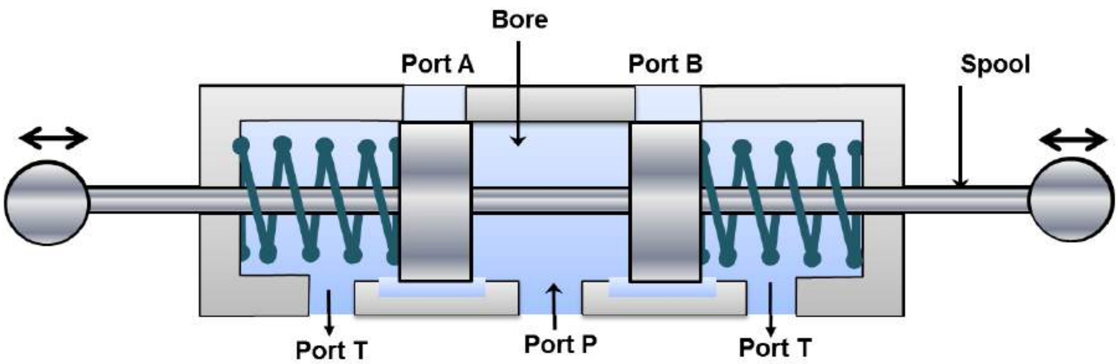


Figure 24 Tandem centred valve

Figure 24 shows a tandem centre three position four way direction control valve. In this configuration, the working ports A and B are blocked and the pump port P is connected to the tank port T. Tandem centre results in the locked actuator. However, pump to tank flow takes place at the atmospheric temperature. This kind of configuration can be used when the load is needed to hold. Disadvantages of high pressure pumping in case of closed centre (shown in Figure 23) can be removed by using this configuration.
The regenerative centre is another important type of common centre configuration used in hydraulic circuits. Regenerative means the flow is generated from the system itself. Regenerative centre is used when the actuator movement in one direction requires two different speeds. For example, the half-length of the stroke requires fast movement during no-load condition and remaining half-length requires slow motion during load conditions. The regenerative centre saves the pump power.

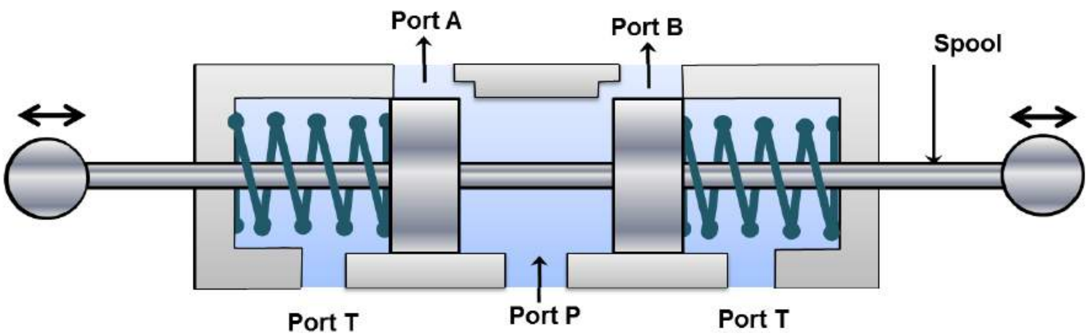


Figure 25 Regenerative Centre

Figure 25 shows the regenerative configuration for the three position four way (3/4) DCV in its mid position. This configuration increases the piston speed. In the mid position pump Port P is connected to A and B, and tank port T is blocked.

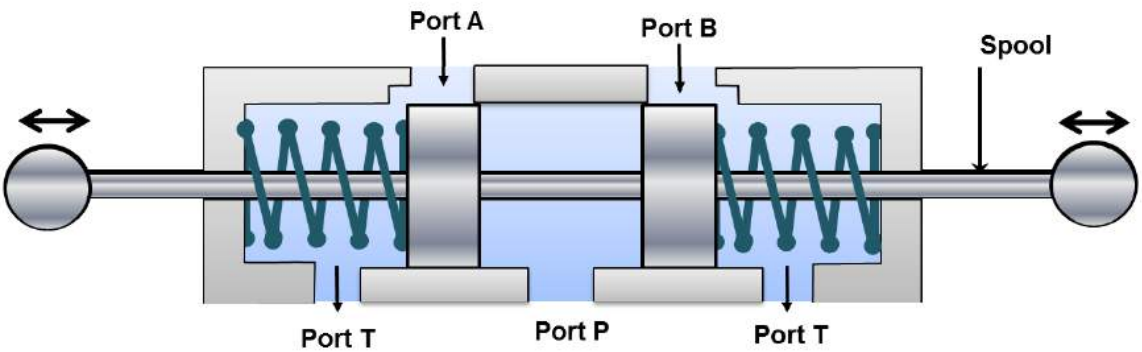


Figure 26 Floating Centre

Figure 26 shows the floating centre 3/4 DCV in its mid position. In this configuration, the pump port is blocked and both the working ports A and B are connected to the tank port T. Therefore, the working ports A and B can be moved freely which is reason they are called as floating centre. The pumped fluid passes through the relief valve. Therefore, pump works in the high pressure condition. This configuration is used only in some special cases.

1.3.2 Two position four way (2/4) valves

The two position four way valves have only two switching positions and do not have any mid position. Therefore, they are also known as impulse valves. These valves can be used to operate double acting cylinders. These are also used to reciprocate or hold an actuator. The operation is faster because the distance between ports of these valves is smaller. Hence, these valves are used on machines where fast reciprocation cycles are needed such as punching and stamping etc.

2. Flow control valves

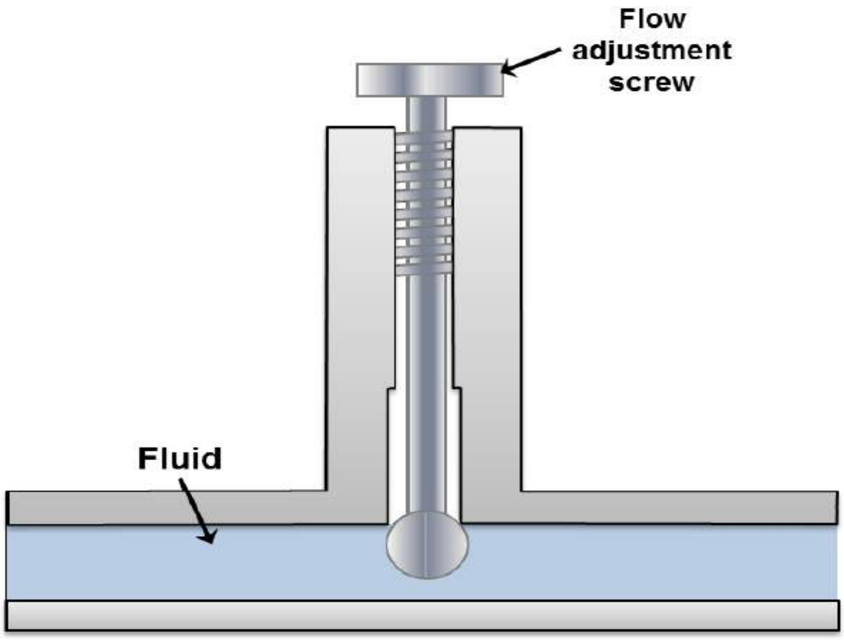


Figure 27- Flow Control Valve

In practice, the speed of actuator is very important in terms of the desired output and needs to be controlled. The speed of actuator can be controlled by regulating the fluid flow. A flow control valve can regulate the flow or pressure of the fluid. The fluid flow is controlled by varying area of the valve opening through which fluid passes. The fluid flow can be decreased by reducing the area of the valve opening and it can be increased by increasing the area of the valve opening. A very common example to the fluid flow control valve is the household tap. Figure 27 shows the schematic diagram of a flow control valve. The pressure adjustment screw varies the fluid flow area in the pipe to control the discharge rate.

The pressure drop across the valve may keep on fluctuating. In general, the hydraulic systems have a pressure compensating pump. The inlet pressure remains almost constant but the outlet pressure keeps on fluctuating depending on the external load. It creates fluctuating pressure drop. Thus, the ordinary flow control valve will not be able to maintain a constant fluid flow. A pressure compensated flow control valve maintains the constant flow throughout the movement of a spool, which shifts its position depending on the pressure. Flow control valves can also be affected by temperature changes. It is because the viscosity of the fluid changes with temperature. Therefore, the advanced flow control valves often have the temperature compensation. The temperature compensation is achieved by the thermal expansion of a rod, which compensates for the increased coefficient of discharge due to decreasing viscosity with temperature.

- Types of Flow Control Valves

  The flow control valves work on applying a variable restriction in the flow path. Based on the construction; there are mainly four types:

  2.1 plug valve

  2.2 butterfly valve

  2.3 ball valve

  2.4 balanced valve.

2.1 Plug or glove valve

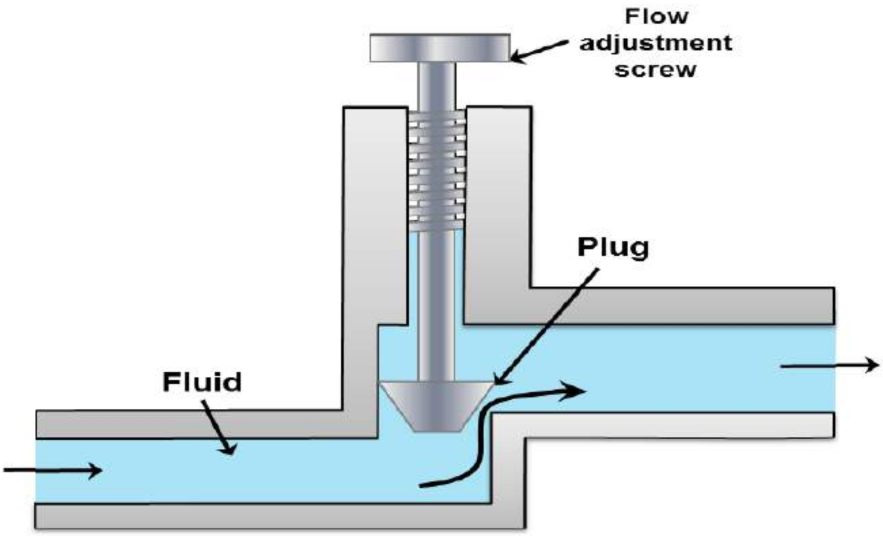


Figure 28 - Plug or glove valve

The plug valve is quite commonly used valve. It is also termed as glove valve. Schematic of plug or glove valve is shown in Figure 28. This valve has a plug which can be adjusted in vertical direction by setting flow adjustment screw. The adjustment of plug alters the orifice size between plug and valve seat. Thus the adjustment of plug controls the fluid flow in the pipeline. The characteristics of these valves can be accurately predetermined by machining the taper of the plug. The typical example of plug valve is stopcock that is used in laboratory glassware. The valve body is made of glass or Teflon. The plug can be made of plastic or glass. Special glass stopcocks are made for vacuum applications. Stopcock grease is used in high vacuum applications to make the stopcock air-tight.

2.2 Butterfly valve

A butterfly valve is shown in Figure 29. It consists of a disc which can rotate inside the pipe. The angle of disc determines the restriction. Butterfly valve can be made to any size and is widely used to control the flow of gas. These valves have many types which have for different pressure ranges and applications. The resilient butterfly valve uses the flexibility of rubber and has the lowest pressure rating. The high performance butterfly valves have a slight offset in the way the disc is positioned. It increases its sealing ability and decreases the wear. For high-pressure systems, the triple offset butterfly valve is suitable which makes use of a metal seat and is therefore able to withstand high pressure. It has higher risk of leakage on the shut-off position and suffers from the dynamic torque effect. Butterfly valves are favoured because of their lower cost and lighter weight. The disc is always present in the flow therefore a pressure drop is induced regardless of the valve position.

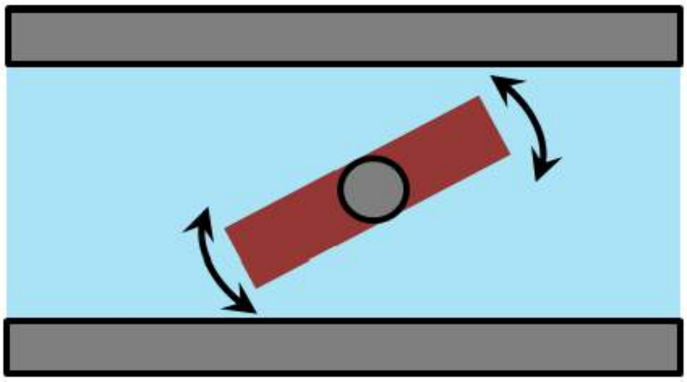


Figure 29- Butterfly valve

2.3 Ball Valve

The ball valve is shown in Figure 30. This type of flow control valve uses a ball rotated inside a machined seat. The ball has a through hole as shown in Figure 30. It has very less leakage in its shut-off condition. These valves are durable and usually work perfectly for many years. They are excellent choice for shutoff applications. They do not offer fine control which may be necessary in throttling applications. These valves are widely used in industries because of their versatility, high supporting pressures (up to 1000 bar) and temperatures (up to 250°C). They are easy to repair and operate.

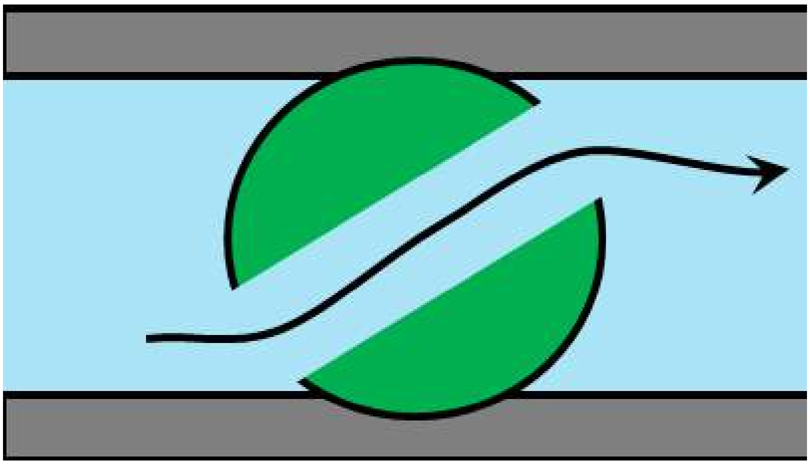


Figure 30- Ball valve

2.4 Balanced valve

Schematic of a balanced valve is shown in figure 31. It comprises of two plugs and two seats. The opposite flow gives little dynamic reaction onto the actuator shaft. It results in the negligible dynamic torque effect. However, the leakage is more in these kind of valves because the manufacturing tolerance can cause one plug to seat before the other. The pressure-balanced valves are used in the houses. They provide water at nearly constant temperature to a shower or bathtub despite of pressure fluctuations in either the hot or cold supply lines.

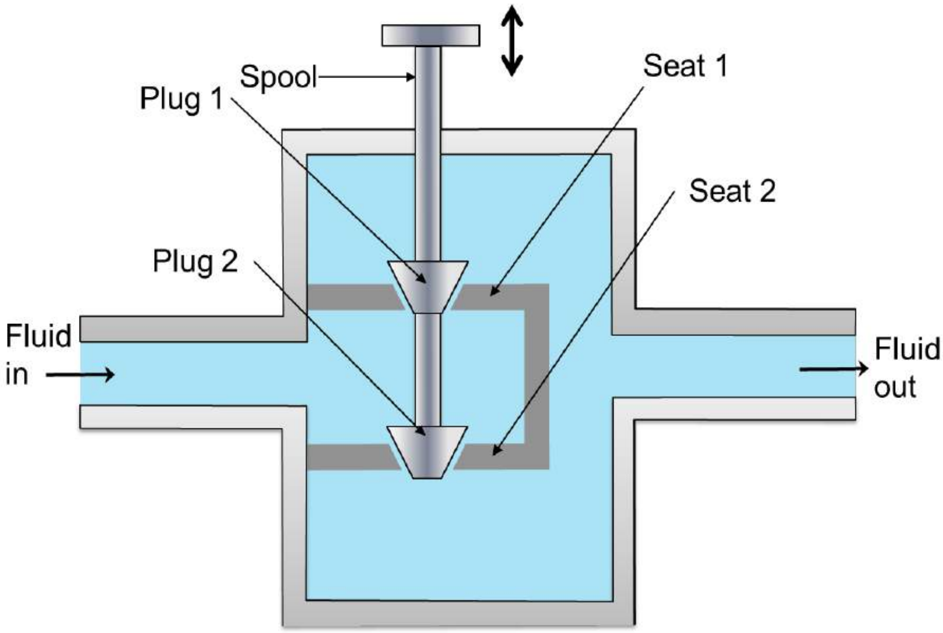


Figure 31- Balanced valve

3. Pressure relief valves

The pressure relief valves are used to protect the hydraulic components from excessive pressure. This is one of the most important components of a hydraulic system and is essentially required for safe operation of the system. Its primary function is to limit the system pressure within a specified range. It is normally a closed type and it opens when the pressure exceeds a specified maximum value by diverting pump flow back to the tank. The simplest type valve contains a poppet held in a seat against the spring force as shown in Figure 32. The fluid enters from the opposite side of the poppet. When the system pressure exceeds the pre-set value, the poppet lifts and the fluid is escaped through the orifice to the storage tank directly. It reduces the system pressure and as the pressure reduces to the set limit again the valve closes. This valve does not provide a flat cut-off pressure limit with flow rate because the spring must be deflected more when the flow rate is higher. Various types of pressure control valves are discussed in the following sections:

3.1 Direct type of relief valve

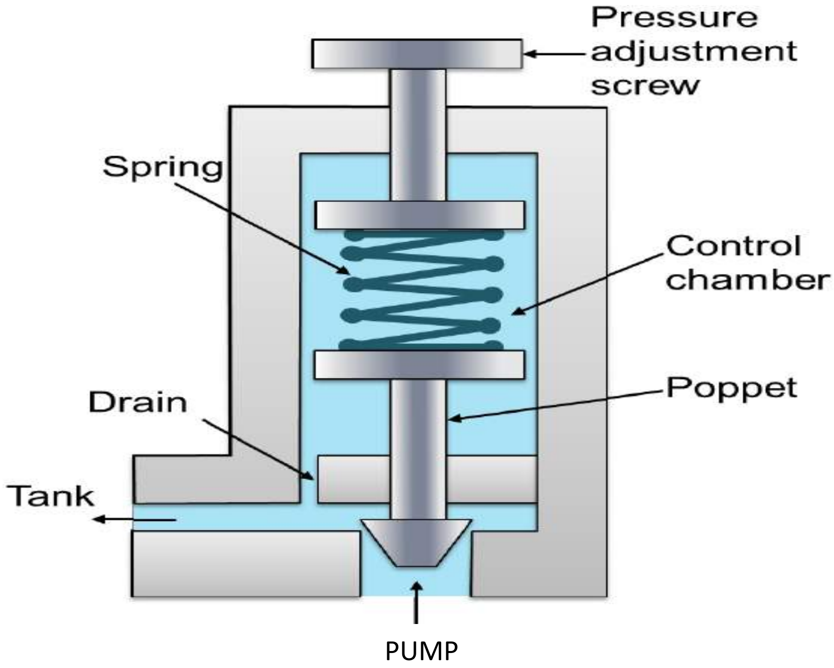


Figure 32 Pressure Relief Valve

Schematic of direct pressure relief valve is shown in figure 32. This type of valves has two ports; one of which is connected to the pump and another is connected to the tank. It consists of a spring chamber where poppet is placed with a spring force. Generally, the spring is adjustable to set the maximum pressure limit of the system. The poppet is held in position by combined effect of spring force and dead weight of spool. As the pressure exceeds this combined force, the poppet raises and excess fluid bypassed to the reservoir (tank). The poppet again reseats as the pressure drops below the pre-set value. A drain is also provided in the control chamber. It sends the fluid collected due to small leakage to the tank and thereby prevents the failure of the valve.

3.2 Unloading Valve

The construction of unloading valve is shown in Figure 33. This valve consists of a control chamber with an adjustable spring which pushes the spool down. The valve has two ports: one is connected to the tank and another is connected to the pump. The valve is operated by movement of the spool. Normally, the valve is closed and the tank port is also closed. These valves are used to permit a pump to operate at the minimum load. It works on the same principle as direct control valve that the pump delivery is diverted to the tank when sufficient pilot pressure is applied to move the spool. The pilot pressure maintains a static pressure to hold the valve opened. The pilot pressure holds the valve until the pump delivery is needed in the system. As the pressure is needed in the Hydraulic circuit;

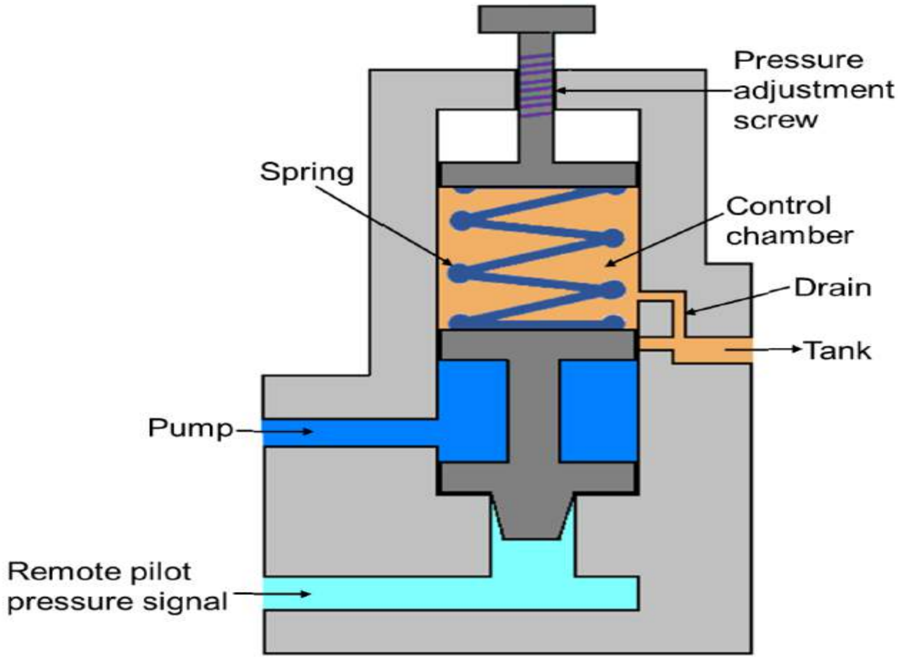


Figure 33- Unloading Valve

The pilot pressure is relaxed and the spool moves down due to the self-weight and the spring force. Now, the flow is diverted to the hydraulic circuit. The drain is provided to remove the leaked oil collected in the control chamber to prevent the valve failure. The unloading valve reduces the heat build-up due to fluid discharge at a pre-set pressure value.

3.3 Sequence valve

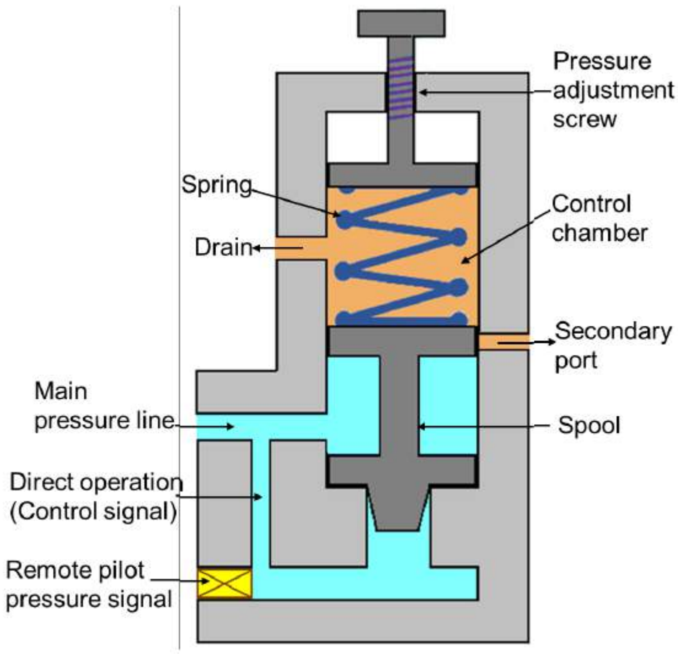


Figure 34- Sequence valve

The primary function of this type of valve is to divert flow in a predetermined sequence. It is used to operate the cycle of a machine automatically. A sequence valve may be of direct-pilot or remote-pilot operated type.

Schematic of the sequence valve is shown in Figure 34. Its construction is similar to the direct relief valve. It consists of the two ports; one main port connecting the main pressure line and another port (secondary port) is connected to the secondary circuit. The secondary port is usually closed by the spool. The pressure on the spool works against the spring force. When the pressure exceeds the pre-set value of the spring; the spool lifts and the fluid flows from the primary port to the secondary port. For remote operation; the passage used for the direct operation is closed and a separate pressure source for the spool operation is provided in the remote operation mode.

3.4 Counterbalance Valve

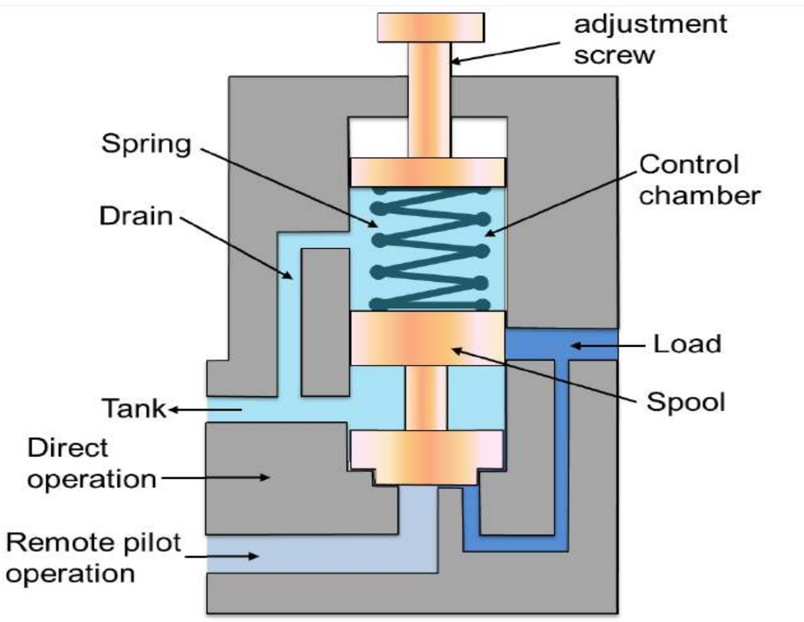


Figure 35- Counter Balance Valve

The schematic of counterbalance valve is shown in Figure 35. It is used to maintain the back pressure and to prevent a load from failing. The counterbalance valves can be used as breaking valves for decelerating heavy loads. These valves are used in vertical presses, lift trucks, loaders and other machine tools where position or hold suspended loads are important. Counterbalance valves work on the principle that the fluid is trapped under pressure until pilot pressure overcomes the pre-set value of spring force. Fluid is then allowed to escape, letting the load to descend under control. This valve is normally closed until it is acted upon by a remote pilot pressure source. Therefore, a lower spring force is sufficient. It leads to the valve operation at the lower pilot pressure and hence the power consumption reduces, pump life increases and the fluid temperature decreases.

3.5 Pressure Reducing Valve

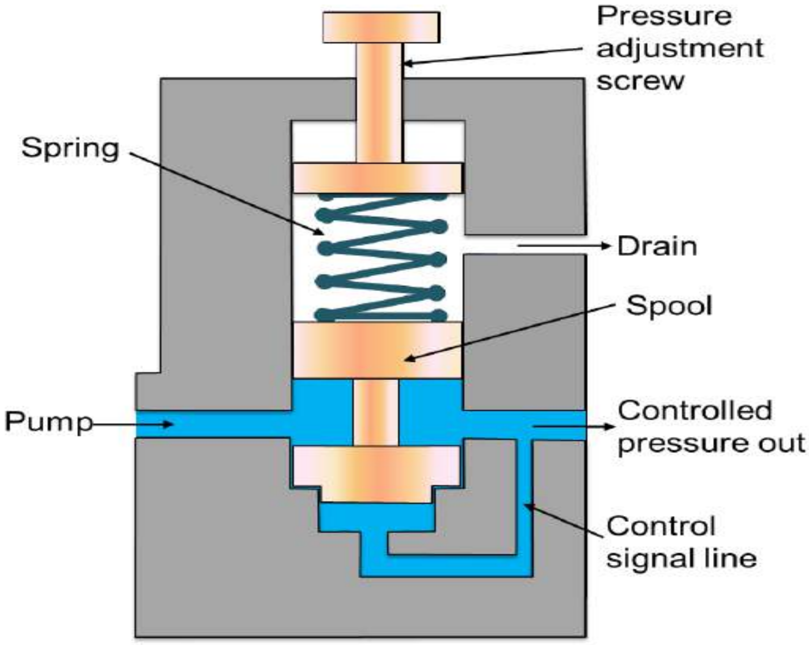


Figure 36- Pressure Reducing Valve

Sometimes a part of the system may need a lower pressure. This can be made possible by using pressure reducing valve as shown in Figure 36. These valves are used to limit the outlet pressure. Generally, they are used for the operation of branch circuits where the pressure may vary from the main hydraulic pressure lines. These are open type valve and have a spring chamber with an adjustable spring, a movable spool as shown in figure. A drain is provided to return the leaked fluid in the spring (control) chamber. A free flow passage is provided from inlet port to the outlet port until a signal from the outlet port tends to throttle the passage through the valve. The pilot pressure opposes the spring force and when both are balanced, the downstream is controlled at the pressure setting. When the pressure in the reduced pressure line exceeds the valve setting, the spool moves to reduce the flow passage area by compressing the spring. It can be seen from the figure that if the spring force is more, the valve opens wider and if the controlled pressure has greater force, the valves moves towards the spring and throttles the flow.

4. GRAPHICAL REPRESENTATION OF HYDRAULIC ELEMENTS.

The hydraulic elements such as cylinders and valves are connected through pipelines to form a hydraulic circuit. It is difficult to represent the complex functioning of these elements using sketches. Therefore graphical symbols are used to indicate these elements. The symbols only specify the function of the element without indicating the design of the element. Symbols also indicate the actuation method, direction of flow of fluid and designation of the ports. Symbols are described in various documents like DIN24300, BS2917, ISO1219 and the new ISO5599, CETOP RP3 and the original American JIC and ANSI symbols.

The symbol used to represent an individual element display the following characteristics:

- Function
- Actuation and return actuation methods
- Number of connections
- Number of switching positions
- General operating principle
- Simplified representation of the flow path

The symbol does not represent the following characteristics:

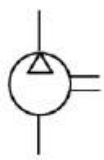
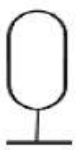
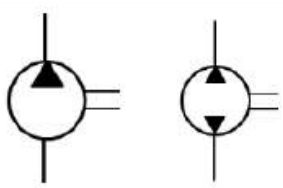
- Size or dimensions of the component
- Particular manufacturer, methods of construction or costs
- Operation of the ports
- Any physical details of the elements
- Any unions or connections other than junctions

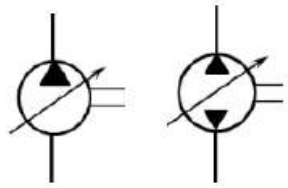
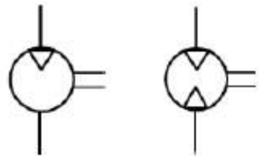
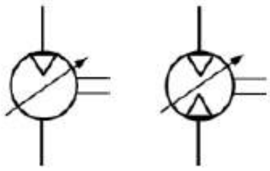
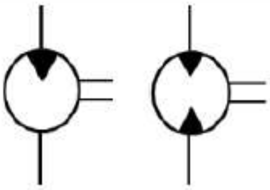
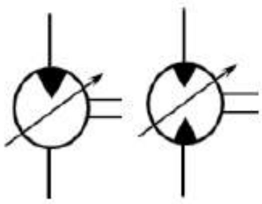
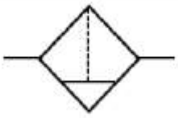
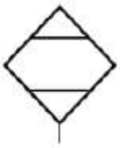
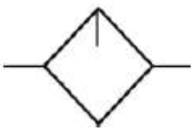
Earlier the ports were designated with letter system. Now as per ISO5599 the ports are designated based on number system. The port designations are shown in table 1.

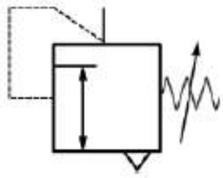
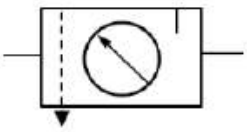
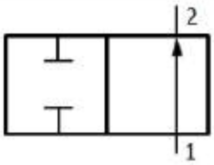
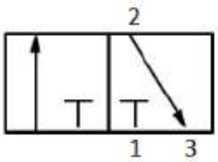
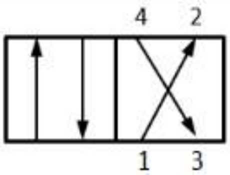
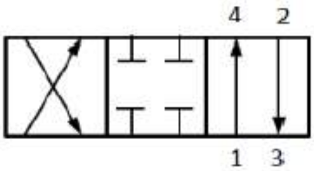
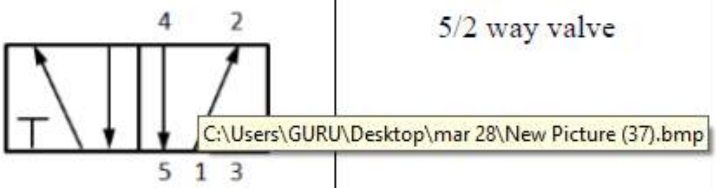
Port	Letter system	Number system
Pressure port	P	1
Working port	A	4
Working port	B	2
Exhaust port	R	5
Exhaust port	S	3
Pilot port	Z	14
Pilot port	Y	12

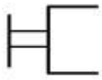
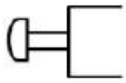
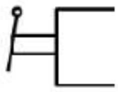
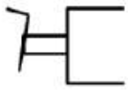
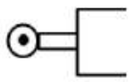
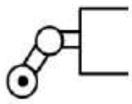
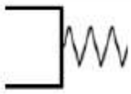
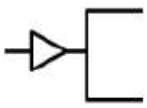
Table1- Symbols of the ports

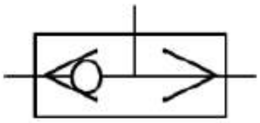
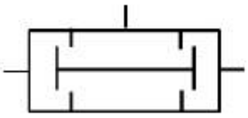
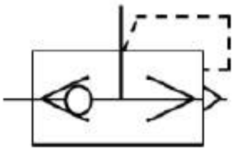
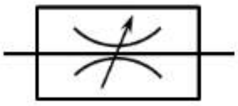
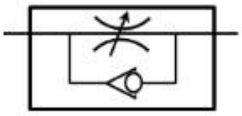
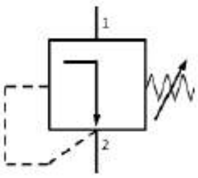
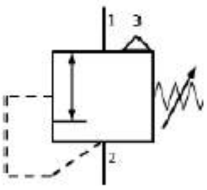
Graphical symbols of hydraulic / pneumatic elements and equipment's

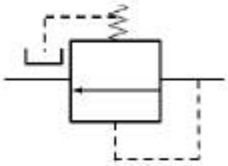
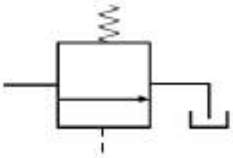
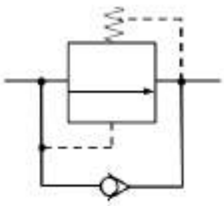
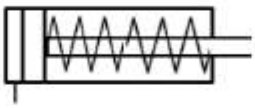
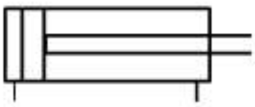
SYMBOL	DESIGNATION	EXPLANATION
Energy supply		
	Air compressor	One direction of rotation only with constant displacement volume
	Air receiver	Compressed air from the compressor is stored and diverted to the system when required
		One direction and two direction of rotation with constant displacement volume

	Hydraulic pump	One direction and two direction of rotation with variable displacement
Rotary actuators		
	Pneumatic motor	One direction and two direction of rotation with constant displacement volume
		One direction and two direction of rotation with variable displacement
	Hydraulic motor	One direction and two direction of rotation with constant displacement volume
		One direction and two direction of rotation with variable displacement
Service units		
	Air filter	This device is a combination of filter and water separator
	Dryer	For drying the air
	Lubricator	For lubrication of connected devices, small amount of oil is added to the air flowing through this device

	Regulator	To regulate the air pressure
	FRL unit	Combined filter, regulator and lubricator system
Direction control valves (DCVs)		
	2/2 way valve	Two closed ports in the closed neutral position and flow during actuated position
	3/2 way valve	In the first position flow takes place to the cylinder In the second position flow takes out of the cylinder to the exhaust (Single acting cylinder)
	4/2 way valve	For double acting cylinder all the ports are open
	4/3 way valve	Two open positions and one closed neutral position
	5/2 way valve	Two open positions with two exhaust ports

Direction control valve actuation methods		
	General manual actuation	Manual operation of DCV
	Push button actuation	
	Lever actuation	
	Detent lever actuation	
	Foot pedal actuation	Mechanical actuation of DCV
	Roller lever actuation	
	Idle return roller actuation	
	Spring actuation	
	Direct pneumatic actuation	Pneumatic actuation of DCV
Non return valves		
	Check valve	Allows flow in one direction and blocks flow in other direction
	Spring loaded check valve	

	Shuttle/ OR valve	When any one of the input is given the output is produced
	AND valve	Only when both the inputs are given output is produced
	Quick exhaust valve	For quick exhaust of air to cause rapid extension/ retraction of cylinder
Flow control valves		
	Flow control valve	To allow controlled flow
	Flow control valve with one way adjustment	To allow controlled flow in one direction and free flow in other
Pressure control valves		
	Pressure relieving valve	Non relieving type
		Relieving type with overload being vented out

	Pressure reducing valve	Maintains the reduced pressure at specified location in hydraulic system
	Unloading valve	Allows pump to build pressure to an adjustable pressure setting and then allow it to be discharged to tank
	Counter balance valve	Controls the movement of vertical hydraulic cylinder and prevents its descend due to external load weight
Actuators		
	Single acting cylinder	Spring loaded cylinder with retraction taking place by spring force
	Double acting cylinder	Both extension and retraction by pneumatic/hydraulic force

5. CASE STUDY.

Design of Hydraulic Circuit

Case study 1

1.1 Problem Definition: Package lifting device

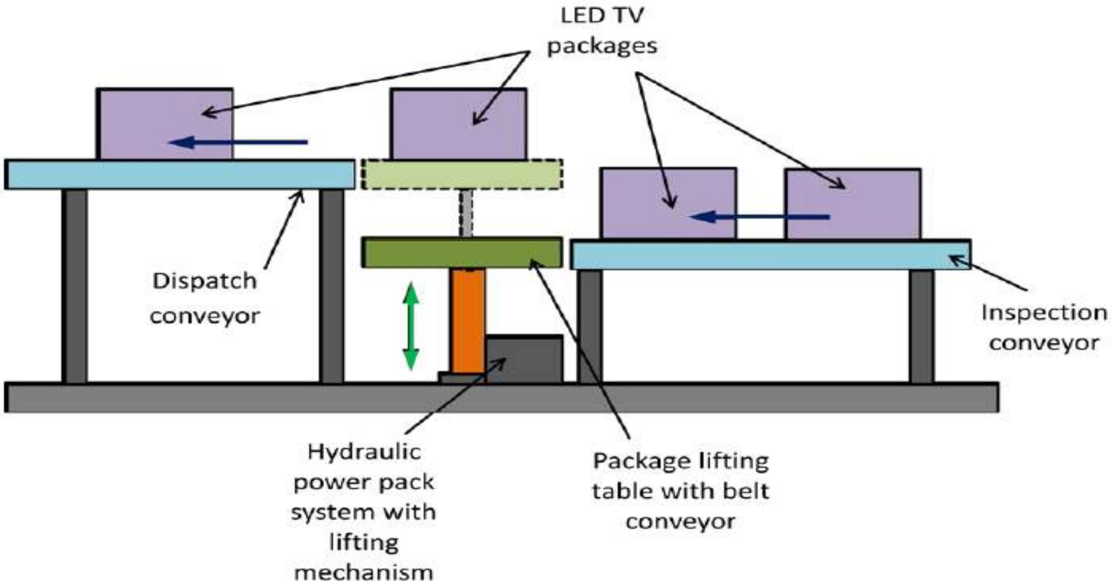


Figure 37- Schematic of a Package lifting system for LED TVs

For a dispatch station of a LED TV production house, design a package lifting device to lift packages containing 21” to 51” LED TVs from the inspection conveyor to the dispatch conveyor. Draw the hydraulic circuit diagram. List the components. Readers are requested to assume suitable data.

Solution

By applying the principle of hydraulics and after studying the various sensors, pumps, valves and hydraulic actuators, the proposed hydraulic circuit is shown in Figure 37. Components required are listed in table 2.

S. No.	Item No.	Quantity	Description
1	1A	1	Two direction Hydraulic Motor with constant displacement volume
2	0Z1	1	Hydraulic Power Pack
3	0Z2	1	Pressure gauge
4	1V1	1	Shut-off valve
5	1V2	1	Pressure relief valve
6	1S	1	Flow sensor
7		5	Hose line
8		2	Branch tee

Table 2 List of Components

Proposed hydraulic circuit and its operation

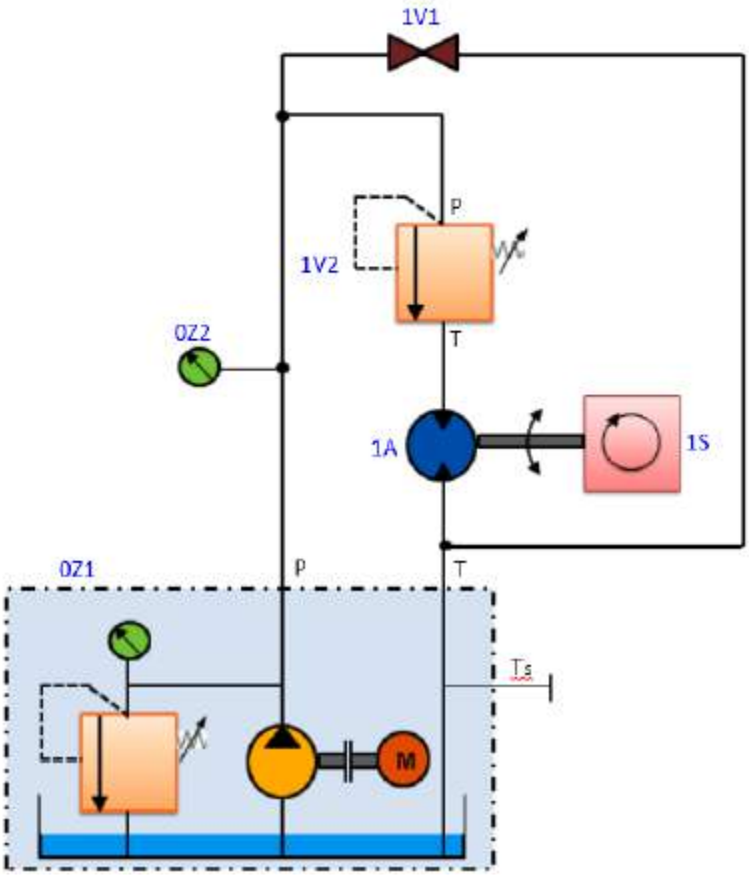


Figure 38- Hydraulic circuit design for package lifting device

Figure 38 shows the circuit design for package lifting device. The two direction hydraulic motor is run by using a hydraulic power pack. Required valves and pressure sensors are also included for desired control action. Readers are requested to carefully read the circuit and comprehend the circuit.

Once the hydraulic circuit has been assembled and checked, valve 1V1 and pressure relief valve 1V2 can be operated in sequence to obtain the rotary motion of hydraulic motor in required direction (clockwise/counter clockwise). This rotary motion can further be converted into linear motion by using suitable motion converter mechanism viz. Rack and pinion mechanism. Linear motion is used to lift the packages. It is required to develop a PID based controller to control the operation of the valves. The pressure gauge and flow sensor are used to monitor the operation continuously.

UNIT-3 Control the Hydraulic system through electrical devices

(Electro Hydraulic).

Objective:

Skill:

At the end of this unit trainees shall be able to

1. Understand those electrical devices which deal with hydraulic components.

Knowledge:

At the end of this unit trainees shall be able to

1. Understand the operation of solenoid valve and control it through relay.
2. Build up the electrohydraulic logics and make the circuits.

Guidelines to Instructor:

Explain the Mechanism of relay .

Structure:

1. Signal flow through a electro hydraulic control system.
2. Switch & relay.
3. Operation of Single & Double Solenoid valve.

1. SIGNAL FLOW THROUGH AN ELECTRO HYDRAULIC CONTROL SYSTEM.

Definition

Electro-hydraulic term is defined from words of electro, which mean electrical and hydraulic which mean hydro/liquid pressure. The electro-hydraulic equipment and system is an integration of electrical and mechanical components with compressed liquid source.

Components

Electro-hydraulic controllers have a hydraulic power section. In an electro-hydraulic control, the signal control section is made up of electrical components, for example, the proximity switches, and relays. The directional control valves behaves as a medium between the electrical signal control section and the hydraulic power section in the controller (refer Figure 1).

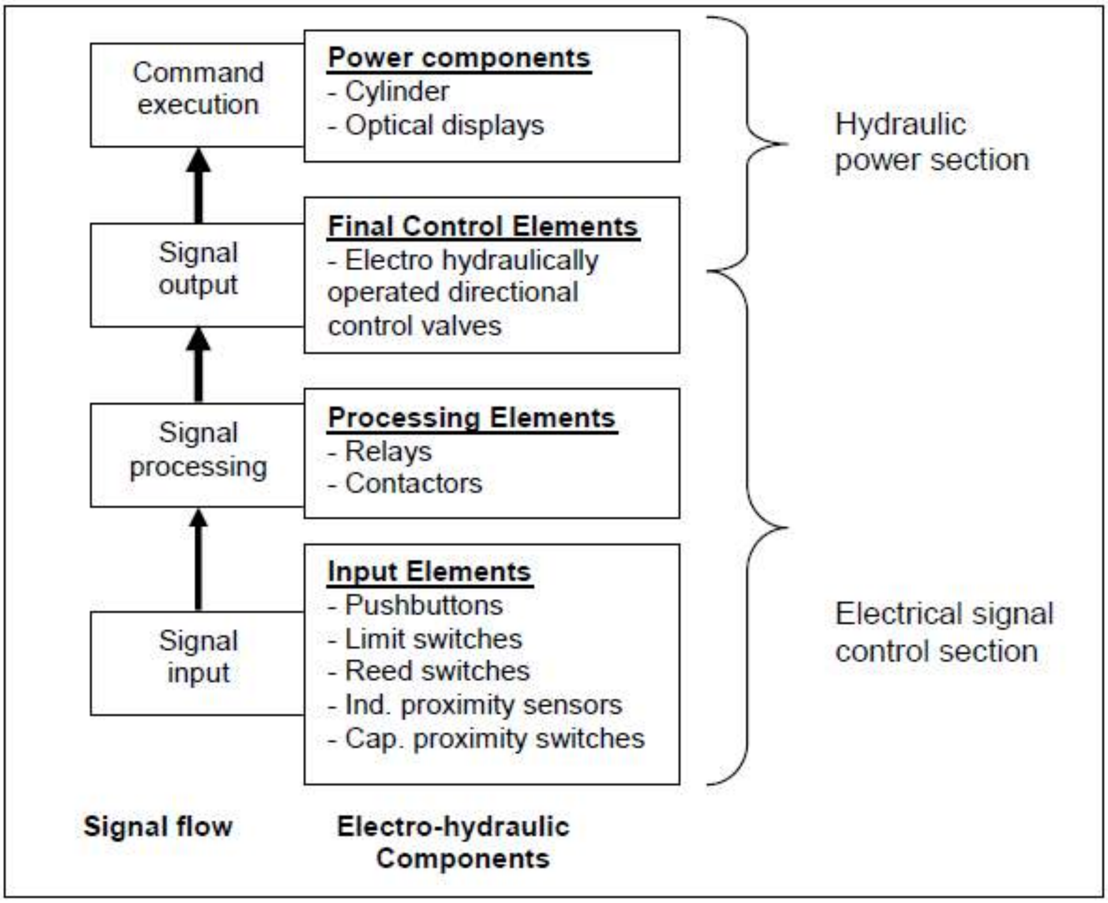


Figure 1: Signal flow and components of an electro-hydraulic control system

2. SWITCH & RELAY

Switch

There are 3 types of electrical switches used in the design of electro-hydraulic circuit. They are:

i) Normally-opened (NO) contact switch (refer **Figure 2(a)**).

ii) Normally-closed (NC) contact switch (refer **Figure 2(b)**).

iii) Changeover contact switch (refer **Figure 2(c)**).

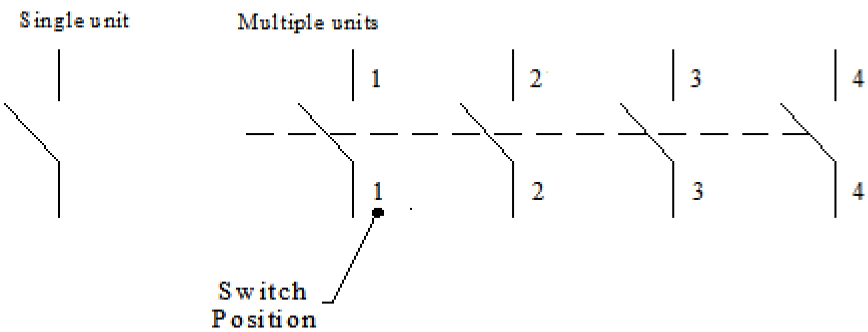


Figure 2(a): Normally-opened contact switches

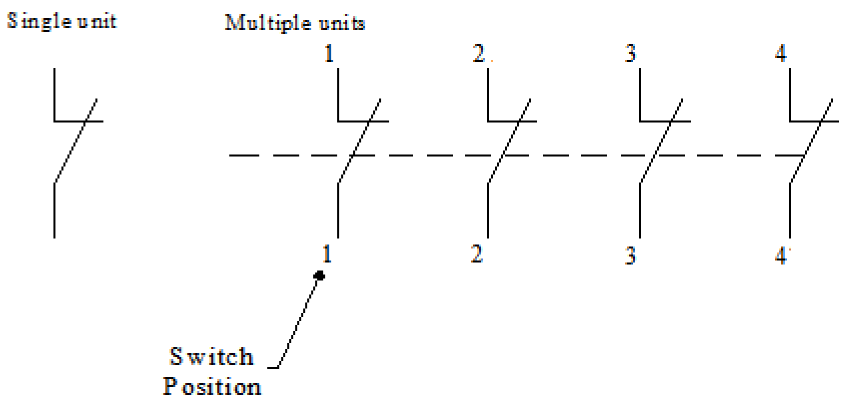


Figure 2(b): Normally-closed contact switches

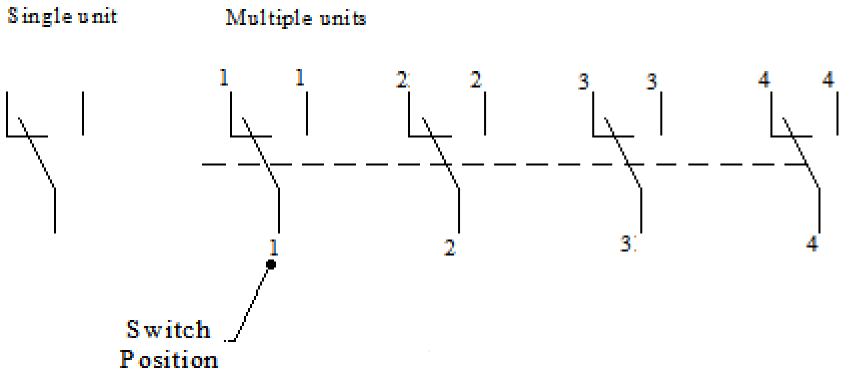


Figure 2(c): Changeover contact switches

Relay

Relay is an electrical device that contains a coil and a contactor switch. Relay also can consist of a coil and multiple contactors. Figure 3 shows a coil (K) with 4 contactor switches. If the coil is activated, the Changeover Contact will change its state. A NO switch will change its state from ON to OFF state.

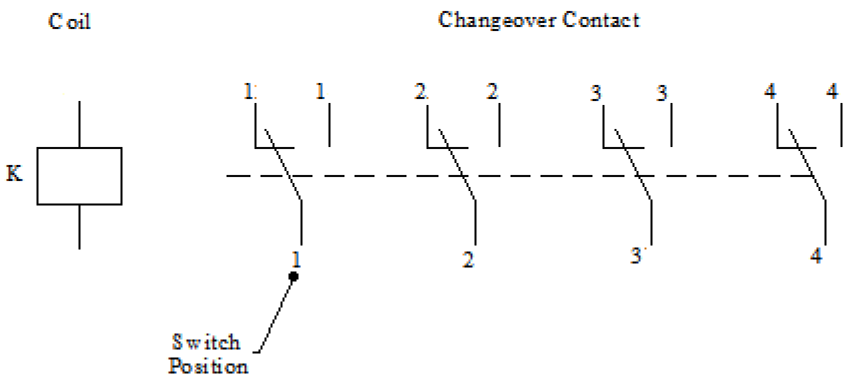


Figure 3: Relay with a coil and multiple contactor switches

3. Operation of Single & Double Solenoid valve.

Solenoid Valve

Solenoid valve is an electro-mechanical device that built-in with a coil (solenoid) and a pneumatic/hydraulic directional control valve (DCV). There are many types of built-in solenoid directional control valve. A few of them are:

- 4/2 Way DCV single solenoid with spring return
- 4/3 Way DCV double solenoid with spring return

Operation of a basic electro-hydraulic circuit using the 4/2 Way DCV Single Solenoid

The 4/2 way DCV single solenoid or mono stable valve consists of a built-in solenoid at the left hand side and a built-in spring at the right hand side of the valve. **Figure 4** shows the hydraulic and electrical circuits (electro-hydraulic circuits) for actuating a double acting cylinder using 4/2 DCV single solenoid. When pushbutton S1 is pressed, coil R1 is activated. Activation of R1 will turn ON the NO K1switch. Once, K1 is ON, it will activate Y1. Solenoid Y1 will change the position of the valve from the original position (right dominant) to the new position (left dominant). The liquid will start to flow into the left side of the cylinder. This will cause the rod of the cylinder to extend.

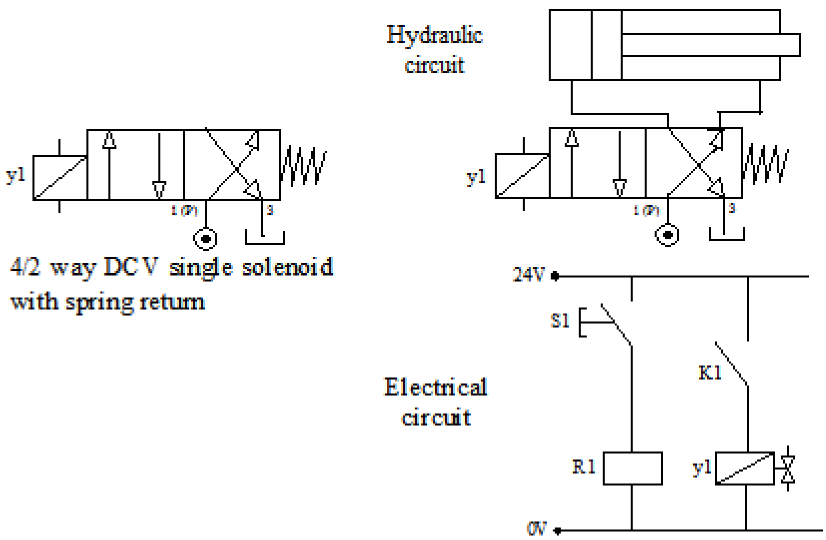


Figure 4: 4/2 DCV single solenoid is used for actuating a double acting cylinder

Operation of a basic electro-hydraulic circuit using the 4/3 Way DCV Double Solenoid

The 4/3 Way DCV double solenoids consists of two solenoids (Y1 and Y2) at the both sides of the valve. It is also called ‘bi stable valve’ or ‘memory valve’. Basically, the 4/3 Way DCV are identical with 4/2 way DCV. The difference is that a centre section is added for 4/3 DCV. Figure 5 shows the hydraulic and electrical circuits (electro-hydraulic circuits) for actuating a double acting cylinder using 4/3 DCV single solenoid. Initially, the 4/3 DCV single solenoid is at a stable state (centre dominant). When pushbutton S1 is pressed, coil R1 will be activated. Activation of R1 will turn ON the NO K1 switch. Once, K1 is ON, it will leads to activation of solenoid Y1. Solenoid Y1 will change the position of the valve from the original position (centre dominant) to the new position (left dominant). On the Other hand, if pushbutton S2 is pressed, coil R2 will be activated. Activation of R2 will turn ON the NO K2 switch. Once, K2 is ON, it will lead to activation of solenoid Y2. Solenoid Y2 will push the position of the valve from the original position (centre dominant) to the new position (right dominant).

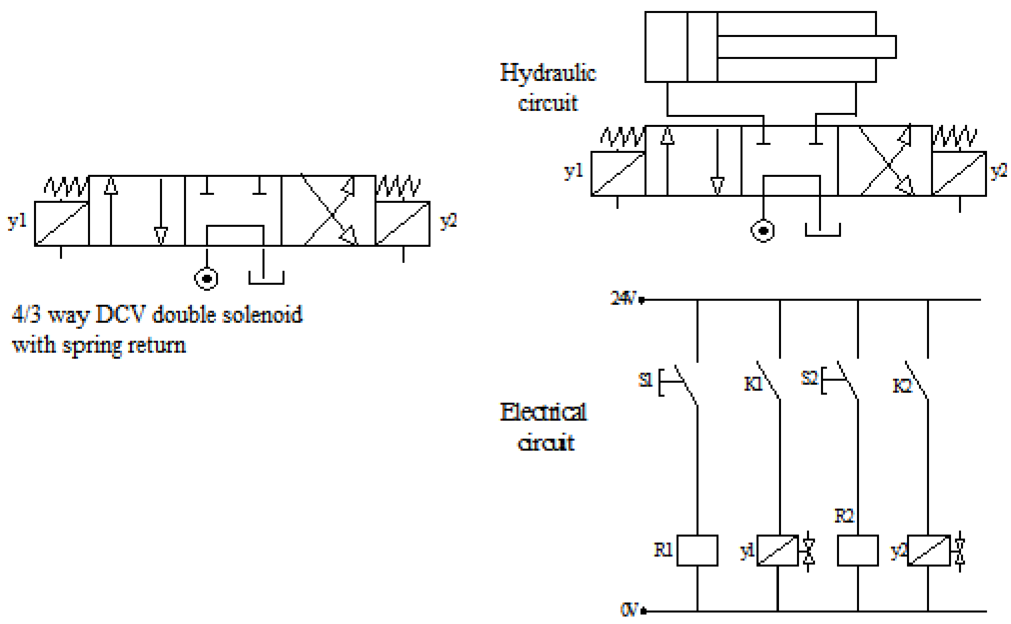


Figure 5: 4/3 DCV double solenoid is used for actuating a double acting cylinder

Operation of the self-holding (memory) electrical circuit

The self-holding electrical circuit is as shown in Figure 6. The function of the circuit is to Provide continuous electrical signal to the circuit even after the pushbutton S1 is released.

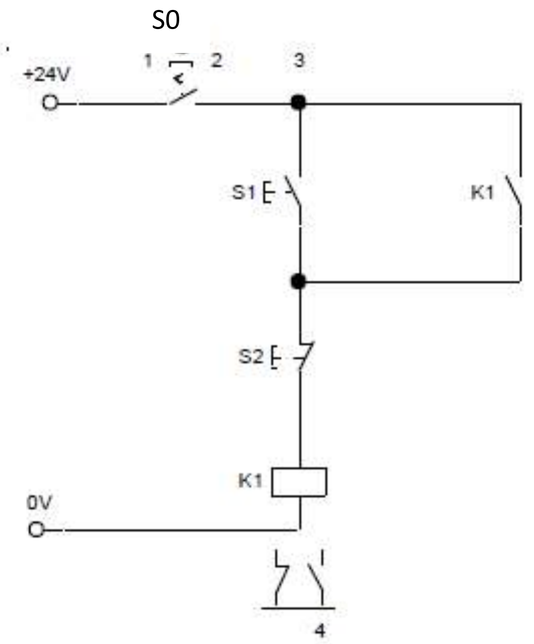


Figure 6: The self-holding electrical circuit.

It is made up of:
1. A NO detent switch, S0.
2. A NO pushbutton, S1.
3. A NC pushbutton, S2.
4. A relay, K1 (with a NO make switch K1).

The operation of the self-holding circuit is as follows:
When the pushbutton S1 is pressed for a short period of time, the coil of relay K1 is activated.

The (changeover contact) switch K1 closes and relay K1 remains activated even after the Pushbutton, S1 is released. Pushbutton S2 is pressed to cancel the self-holding effect. Detent switch S0 is use as a safety switch.

UNIT-4 EXAMPLES OF ELECTRO HYDRAULIC PROGRAMMING AND CONTROL IT THROUGH P.L.C

Objective:

Skill:

At the end of this unit trainees shall be able to

1. Control Electro Hydraulic devices Through PLC.

Knowledge:

At the end of this unit trainees shall be able to

1. Develop the P.L.C Logic.
2. Connect and operate all the Hydraulic components through P.L.C

Guidelines to Instructor:

Explain the Connection between P.L.C and Hydraulic Devices.

Structure:

1. Example
2. A Project.

1. EXAMPLE

When we press a toggle switch button, piston of a double acting cylinder move to the forward direction until we press the stop button it will not to be retracted.

Solution:

STEP-1

At first we set up the Hydraulic Devices through the distributor ports which is connected to the Oil reservoir tank. So, here we need a double acting cylinder, a directional control valve (4/2 Single solenoid coil),PLC s7-300,Hose pipe(4 pices).

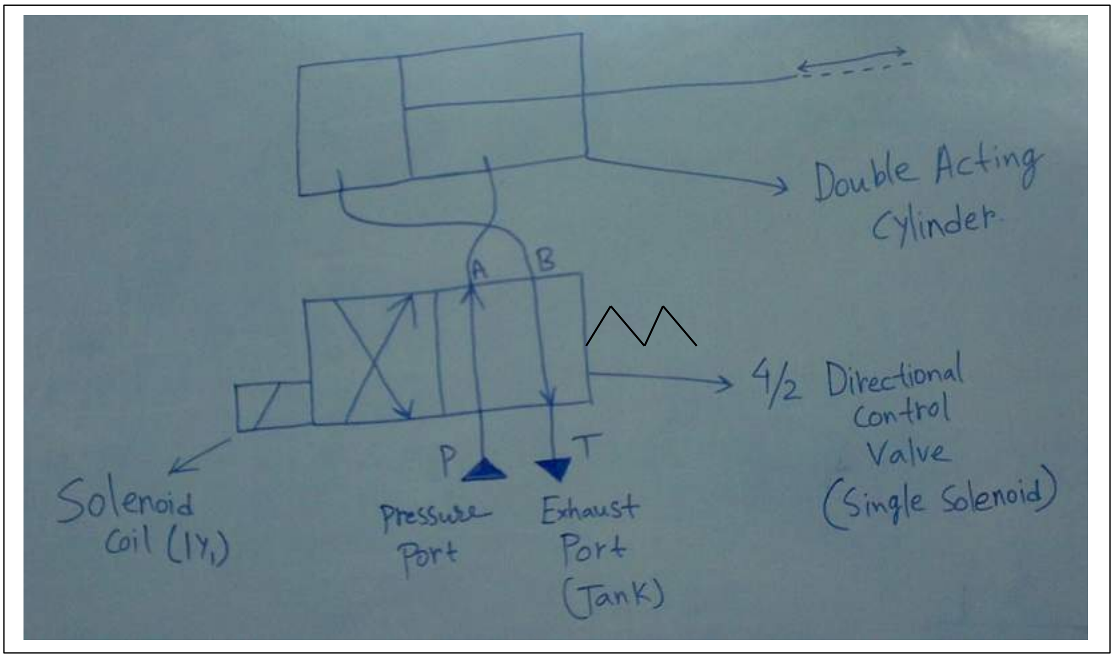
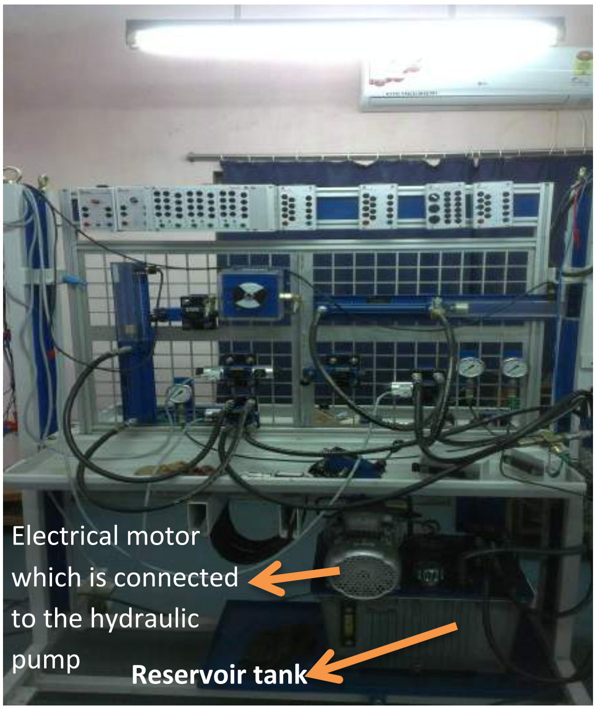


Figure 1-Circuit Diagram

This is the circuit diagram according to our set up. Here we use 4/2 directional control valve (it has 4 ports and 2 switching state.4 port means 1 for exhaust,2 for actuation and 1 for pressure). We have a solenoid coil (1Y1), our main intention is to energized this part of the circuit through the P.L.C.



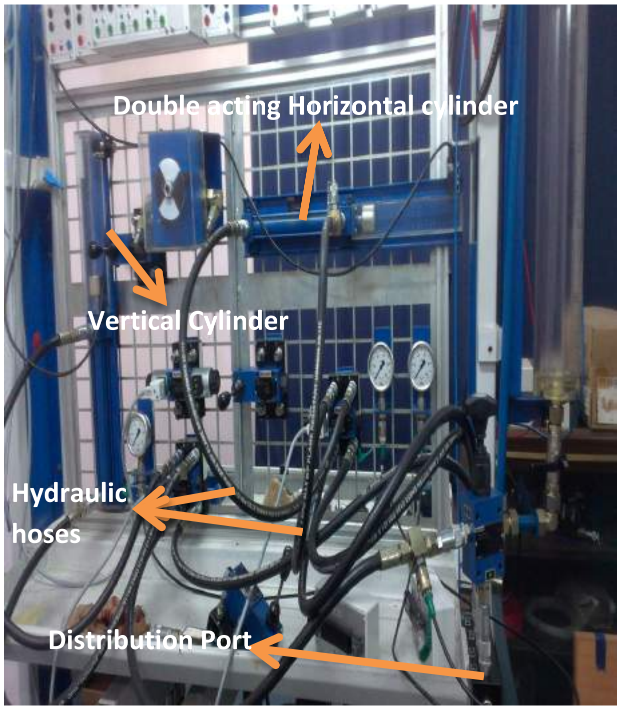


Figure 2 & 3- Hydraulic Assembly

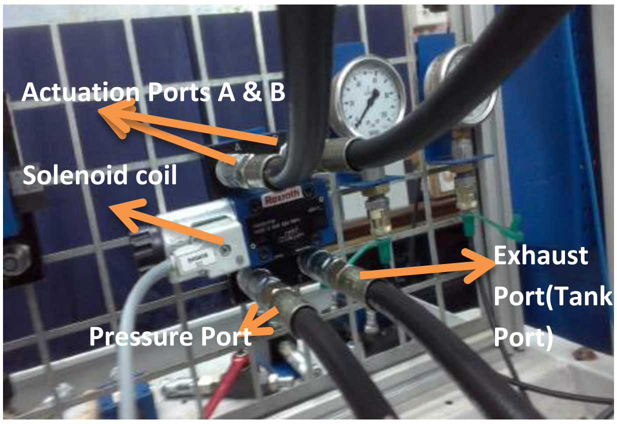


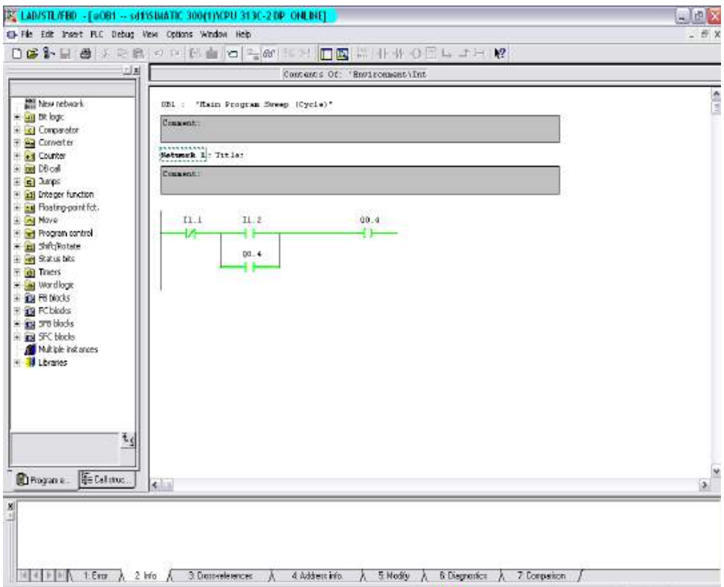
Figure 4-4/2 Directional control valve (With single solenoid)

STEP-2

In this step we connect the Hydraulic system to the PLC

Figure 5 & 6- s7-300 trainer & the total set up.

Now we build up the ladder diagram programme through step 7 simatic manager.



Here, I1.1=STOP Button

I1.2=START Button

Q0.4= Solenoid valve

Figure-7

2. A Project.

Let’s do a project when we press the start button horizontal double acting cylinder move to the forward direction after that vertical double acting cylinder move to the upward direction ,when it reach to the upward direction the horizontal one retract back and when horizontal one completely retracted then the vertical one retract back. This process is continuously going on until we press the stop button.

Solution:

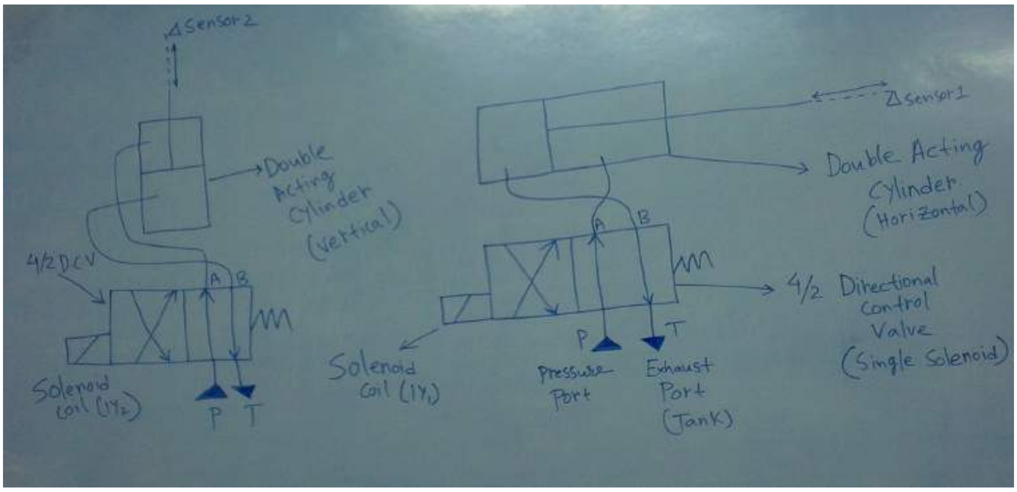


Figure-8 Circuit Diagram

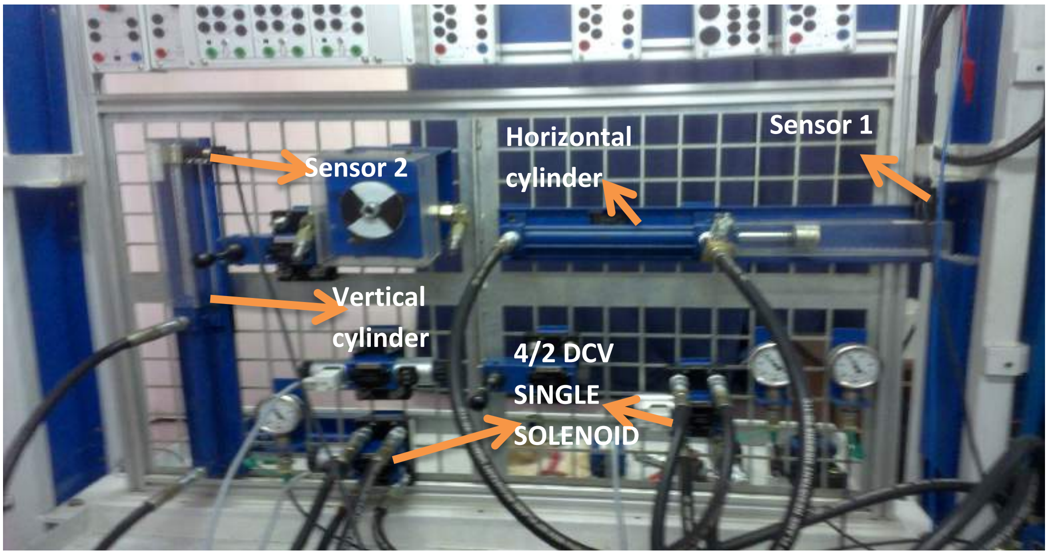


Figure 9- Physical set up

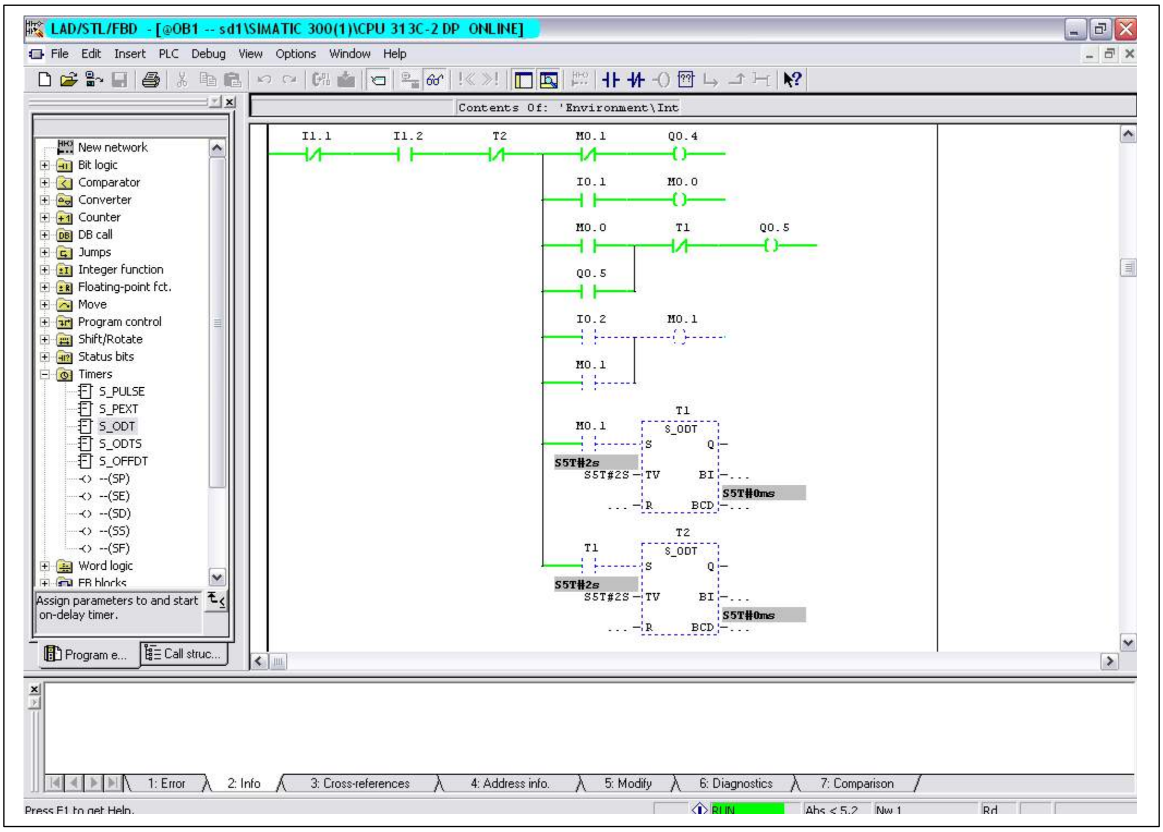


Figure 10-Ladder Diagram logic for this project

I1.1= STOP BUTTON

I1.2= START BUTTON

Q0.4= HORIZONTAL DOUBLE ACTING CYLINDER

Q0.5=VERTICAL DOUBLE ACTING CYLINDER

I0.1=SENSOR 1

I0.2=SENSOR 2

M0.0 & M0.1=MEMORY

T1 & T2=ON DELAY TIMER (SET VALUE 2 SECOND)